Alberta. Commission to Conduct an Inquiry into Causes and Conditions Contributing to Floods in the Bow River at Calgary.

REPORT

6881-R14

NO. 2

INDEX

LIST OF FIGURES AND PLATES.

The Commission thanks Calgary Power Ltd. for supplying nearly all of these illustrations.

NOTE: The numbers are not in consecutive order.

Plate 4 1926 R.C.A.F. Photograph
Bowness District

5 1926 R.C.A.F. Photograph
Bowness District.

I INTRODUCTION

On account of serious flooding, from time to time in the Bow Valley, resulting in damage to buildings and property in the Bowness, Calgary and surrounding area adjacent to the river, the Government of the Province of Alberta deemed it expedient and in the public interest to cause an enquiry to be made into this matter.

Pursuant to the provisions of the Public Inquiries Act, chapter 139, R.S.A. 1942, the following were appointed by Order-in-Council to conduct this enquiry:-

W. J. Dick, Professional Engineer of Edmonton; Commissioner (Chairman)
D. W. Hays, Professional Engineer of Medicine Hat; Commissioner
Angus McKinnon of Dalemead, Farmer; Commissioner.

Commission Counsel, J. Mahaffy, Q.C., Calgary.

The terms of reference, as set out, were as follows:-

(1) To investigate the cause of the flooding in the Bow Valley and any conditions aggravating the said flood, having regard to,-

(a) The natural increase in the level of the water in the Bow River during the winter months due to ice jams or other natural causes;

(b) The effect of increasing the average winter flow and level of the water in the Bow River by reason of storage reservoirs constructed in the head waters of the Bow River by the Calgary Power Limited;

(c) The effect of fluctuating the winter flow and level of the water in the Bow Rifer due to the operation of power plants constructed by the Calgary Power Limited;

(d) Such other causes or contributing factors as the Commissioners may consider contribute to the flooding of the areas hereinbefore mentioned.

(2) To report to the Lieutenant-Governor in Council as to what steps might be taken, or what remedies might be adopted to remove or alleviate the danger of flooding and to remedy the situation caused thereby in the Bow River Valley.

(3) To report to the Lieutenant- Governor in Council as to what further steps might be taken to prevent or minimize the resulting damage to buildings and property in the said areas.

II GENERAL

Flooding caused by rivers overflowing their banks has been known to man since the earliest Biblical times. Geological history also reveals many evidences of flooding of ancient rivers. Flooding is therefore, of quite common occurrence, but only becomes 'news' when damage to life and property occurs. Flooding may be described, roughly, as three kinds:-

(a) Spring or summer floods;

(b) Spring or winter break-up floods;

(c) Winter floods.

In the case of (b) and (c) ice is the primary factor causing flooding, but it is especially (c) or winter floods with which this Commission has to deal.

(a) Spring or summer floods occur generally when unusual conditions of precipitation, melting snow, or run-off happens which supply a greater quantity of water than the river channel can immediately carry. Good examples are the recent Winnipeg and Fraser River floods.

The preservation of forest cover, as well as the growing of shrubs and grasses to prevent denudation of river drainage areas, as well as storage, both great and small, all tend to hold the water back and let it out gradually into the rivers and thus tend to prevent spring and summer floods. In this connection it is worthy to note and commend the action of the Province of Alberta and the Dominion Government on the formation of the Eastern Slope of the Rocky Mountains Conservation Board. The purpose of this Board is to conserve the forest cover and water supply with consequent regulation of the rivers rising on the Eastern slope of the Rocky Mountains. The effect of this work is of extreme importance to the three Prairie Province from the standpoints of irrigation, power development and water supply for farms and cities, as well as being a factor in preventing spring or summer floods.

(b) Spring or winter break-up floods. These occur as a natural condition of nature and can be prevented by the work of man assisting in providing an open channel for the break-up before the whole mass of ice is ready to move out and without the ice jamming. Examples of spring or winter break-up floods recently were at Medicine Hat and on the Saskatchewan River in Saskatchewan.

(c) Winter floods. As stated previously, the cause of winter flooding is due to ice. Whenever there is any obstruction in a river it naturally follows that the flow is impeded and therefore there is a rise in the river level on the upstream side which will be referred to, in this report as a rise in the backwater. It is evident, therefore, that where ice jams occur in a river there is a rise in the backwater and if the jam is sufficient to back the water up to a level higher than the banks of the river, the river overflows its banks at this place and flooding occurs.

SUMMER FLOODS ON BOW RIVER IN CALGARY

July 1902 flood

Looking northerly at Bow Marsh Bridge and site of Hillhurst district from south shore of Bow. Break in water surface indicates position of apron dam of Eau Claire diversion structure.

Bow River in flood on June 18, 1897, looking east. Note the Langevin Bridge on the left. The white house beside the stable is No. 410 - 4th St. East. This house was owned by Mr. Birnie.

This is a very brief outline of the cause of winter flooding and is too general in character to apply to our specific problem on the Bow River so we will digress for a moment and describe the history and development of the Bow River system and then return to the problem and treat of it under Winter Floods.

III HISTORY AND DEVELOPMENT OF THE BOW RIVER

This matter will be discussed under the following heads:-

(a) Geographical Description;
(b) General Geology;
(c) Temperature, Precipitation and Run-off;
(d) Power Possibilities and Storage;
(e) Power Developments and Storage Works constructed to date;
(f) Future development of the Bow River;
(g) Importance of Bow River developments to the people of Alberta.

(a) Geographical Description. The Bow River rises at Bow Lake at an altitude of 6,800 feet. This lake is situated some 52 miles west of Banff on the Continental Divide between Alberta and British Columbia.

The main tributaries west of Calgary are Spray, Cascade, Kananaskis, Ghost and Jumping Pound. The Elbow joins the Bow at east Calgary and forms the water supply of that City.

The Spray also rises near the Continental Divide and flows in a northerly direction and enters the Bow just east of Banff.

The Cascade River rises north of Banff and flows into Lake Minnewanka and then into the Bow a few miles east of Banff.

The Kananaskis River rises at Kananaskis Lakes near the Continental Divide, some fifty miles east of Banff and enters the Bow at Seebe, a few miles east of Exshaw.

The Ghost River rises near the source of the Cascade River and flows in an easterly direction to enter the Bow some ten miles west of Cochrane.

The Jumping Pound is a comparatively short river with a smaller drainage area and rises in a foothill area and flows in a northerly direction to enter the Bow a few miles west of Cochrane.

The Elbow is a long river, rising near the Continental Divide in the vicinity of the source of the Kananaskis River and flows in a north-easterly direction to enter the Bow at East Calgary.

The significant features of the Spray, Cascade and Kananaskis Rivers are that they rise in the high mountainous area, are glacier fed, and have lakes at their head, or flow into lakes enroute to the Bow, also the upper reaches of the Ghost River is in proximity to Lake Minnewanka.

In general, the characteristics of all these rivers, with their tributaries including the Bow, are that of turbulent rivers with high gradient and rise in the high land under conditions of snow and ice, so that for more than half the year there is a great variation in flow between the winter and summer months.

(b) General Geology. All of these rivers take their rise and flow, due to the uplift of the Rocky Mountains during past geological times when the limestone beds formed from the old sea which covered the whole of Alberta were thrust up to the surface to form the Rocky Mountain barrier. The rivers with their source in the Rocky Mountains flow through the complete geological section from the Cambrian to the Upper Cretaceous. In general, the older rocks are quartzite and limestones, while the latter are composed

largely of shales with alternating layers of thinly bedded sandstones. The nature of the topography of the Bow River Valley has been determined by these geological conditions, for example:-

In the area of Rocky Mountain uplift, the altitude of the Bow is some 6,860 feet. It follows a tortuous course to the south east down a flat bottomed valley for 90 miles before emerging from the mountains at Seebe at an elevation of 4,200 feet. This course is through older and more resistant rocks. From this point on, it flows through a foothill country composed of alternate sandstone and shales. The shales are easily eroded, but the sandstone bands, being less easily eroded, form waterfalls or riffles, and in some cases provide suitable foundations for dam sites. The nearer to Calgary the younger and more easily eroded rocks occur. Calgary is some 55 miles from Seebe and the elevation of the former is 3,403 feet or a drop in the river level of some 800 feet. The result of these conditions is that in general the valley of the river west of Calgary to Seebe is more or less deeply entrenched.

(c) <u>Temperature, Precipitation and Run-off</u> are the principal factors affecting stream flow. During extremely cold weather, the flow of a river or tributary may be entirely curtailed by the formation of ice. On the other hand, in the event of chinooks or warm weather there is a rising stage in the river. Run-off may be rapid or slow, dependent on the nature of the drainage area. Bare rocks or areas denuded of forest cover, or forest growth, have a rapid run-off. On the other hand drainage areas with forest cover, swamps and lakes, serve as a 'blotting paper' to hold back the water and give it out gradually.

The average precipitation of the Bow Valley is comparatively small being about 21.7 inches per year at Banff of which 7.7 inches is due to snow and ice. The latter is therefore locked in during the fall and winter months resulting in a minimum flow during this period.

The hydrograph on Fig. 2 will serve to illustrate the extreme variation in natural flow which, unless corrected by means of storage or conservation of water by man-made works, would limit the river to a very minor role in providing power for the development of Alberta.

In this connection it is interesting to quote from a letter written by Mr. C. H. Mitchell, Consulting Engineer, in March 1914 to the then Superintendent of the Water Power Branch at Ottawa, when submitting his report on the original investigations of the Bow River:-

> "The Bow River is peculiar in that, in its natural condition, its high-summer flow discharge is upwards of seventy times its low-water winter discharge, a condition which obviously renders its use in its present state, unsuitable, inefficient and commercially unfeasible for power purposes. The investigations which have been carried on during the past two years, the result of which have been embodied in the general report to Mr. Hendry and in which I have collaborated, indicate that if the Bow River is to be an efficient commercial source of power and at the same time to afford an ample water supply for irrigation purposes, it is absolutely necessary that the river be regulated and controlled so as to ensure a fixed and useful supply of water continuously throughout the year."

This was written before the full extent of the variation on the Bow was appreciated. It is now estimated that the unregulated flow of the Bow in high summer flood would be some 300 times the unregulated minimum winter flow. It is apparent, therefore, that the power possibilities could only be secured by regulated flow, involving dams to store summer run-off water and give it out in the winter months.

(d) Power Possibilities and Storage. Although the Bow River in its natural state was unsuited for power development fortunately, lakes near the headwaters of the large tributaries could be enlarged by the construction of dams and used for storage purposes. These lakes are Minnewanka, Spray and Kananaskis. It was also fortunate that these lakes were situated at high altitude and the consequent high gradient of the Bow and its tributaries made a number of power sites available that could be developed to use the water over and over again downstream after storage facilities had been provided.

(e) Power Development and Storage Works Constructed to date. Now follows:- "The History of Hydro-Electric Development on the Bow River", "Operation of Calgary Power Plants and Storages on the Bow River" taken from the brief of the Calgary Power Ltd. as submitted to the Commission. This is factual information and is accepted:-

HISTORY OF HYDRO-ELECTRIC DEVELOPMENT ON THE BOW RIVER

"The first hydro-electric development on the Bow River was that of the Calgary Water Power Company in Calgary in 1891. This initial installation was a low head development of 780 h.p. It was operated in parallel with a stream plant to supply power to customers in the central part of the City as well as meet the requirements of the parent lumber industry. Owing to persistent trouble with ice it was subject to winter shut-down and hence could only be regarded as a source of secondary energy to replace steam generation when available. It continued to operate until 1928 when taken over by Calgary Power Ltd.

"The first plant constructed by Calgary Power Ltd. was that at Horseshoe Falls begun in 1909 and placed in operation in 1911 to supply a 5,000 h.p contract with the Canada Cement Company, a 3,000 h.p. contract with the City of Calgary, and another small contract with the Village of Cochrane. This plant was a pioneering enterprise undertaken before any record of stream-flow measurement was available. It had only a small forebay to accommodate hourly variations in load, and when it was placed in operation it was found that not only was normal winter flow much lower than anticipated, but, moreover, in severe winter weather for periods of four or five days on end the river flow was arrested by ice jams upstream and the plant output reduced to 2,500 h.p or less.

The immediate need for storage upstream was apparent, and in 1912 a reservoir of 44,000 acre feet capacity was created at Lake Minnewanka. This was followed in 1913 by the completion of the Kananaskis Falls plant, another run-of-river development, to enable the Company to meet the contract demands of its customers, and, whereas the Horseshoe plant had been designed to utilize 2,700 c.f.s. of water the Kananaskis capacity was reduced to 1,900 c.f.s. in an attempt to conform with actual water available. Even this reduced capacity was more than the river could supply when at times during the winter the natural flow fell as low as 300 c.f.s.

"The Minnewanka reservoir had been constructed having in mind the varying release of water to suit the changing requirements at the power plants, but it proved to be too far upstream for the water to reach the plants unimpeded by ice in cold winter weather, the very time it was most needed. Obviously, the only remedy to this trouble was the construction of a power plant at the outlet of a large reservoir, thus affording a dependable power supply to make up deficiencies elsewhere regardless of weather conditions. Intensive study disclosed several such projects, particularly the Cascade site of 23,000 h.p. which involved enlarging the Minnewanka storage to 180,000 acre feet.

"Unfortunately the Company was precluded from developing either the Spray or Cascade sites by reason of complications in connection with the Banff National Park. In the meantime the Company's business was changing from the wholesale supply of two large customers. Commencing in 1927 it embarked on a programme of expansion of transmission and distribution facilities in the southern half of Alberta. At the same time the Company's generating facilities were becoming inadequate and it was forced to turn its attention to several undeveloped sites on the Bow River below its plant. The Ghost site some 15 miles below Horseshoe plant, was chosen as providing the most storage in combination with a power development and construction was undertaken in 1928. The head was raised to 110 feet as compared with the 50 feet originally proposed in Water Resources Paper No. 2 and the necessary storage thus obtained. At the same time the location of the power station on the downstream face of the main dam made it possible to install additional capacity at a relatively low incremental cost, and the plant was designed to carry peak loads. Two 18,000 h.p. units plus one 1,450 h.p. unit was installed with provision left for the installation of a third 18,000 h.p. unit at a later date. The 1,450 h.p. unit is capable of discharging 150 c.f.s. and was provided to maintain a small flow in the river during off peak hours when the plant would otherwise be shut down completely. When all three existing machines are operating at full load the plant is capable of discharging 3,700 c.f.s.

"The Ghost plant was brought into operation late in 1929, and the additional energy available made necessary a still further search for new markets. A transmission line was constructed to Edmonton for interconnection with the steam plant of that City and resulted not only in providing a market for the Company's surplus energy, but also in enabling the Company to call upon Edmonton for any deficiency that might occur during the

during the low water months of winter. The power supply of the Province was thus strengthened and added impetus given to widespread distribution of electric service.

"Unfortunately this programme of expansion was followed shortly by the depression and later by a period of relatively poor crops. The demand for power fell off and there was urgent need for retrenchment. The Company, however, retained its faith in the future of Alberta and continued to chart a course for still greater expansion to meet the needs which it was confident would come again. Being denied the Cascade and Spray sites, it continued the search for storage and power and turned in 1931 to the Upper Kananaskis Lake.

"In Water Resources Paper No. 2 the storage possibilities of the Kananaskis Lakes were adversely reported on (see page 116). The Company, however, was not satisfied and began detailed surveys in 1930-31. The results indicated that both storage and power could be obtained economically on the Upper and Lower Lakes. Construction was undertaken immediately and an initial reservoir of 36,000 acre feet capacity was created on the Upper Lake in 1932.

"The Company emerged from the depression with generating facilities in excess of load requirements, but with the approach of war the demand again began to rise and in 1940 the signing of a contract with the Ammonia plant being constructed south of Calgary necessitated further expansion on the part of the Company. In the meantime the Company was at last successful in getting permission to proceed with the Minnewanka Development as a war measure, it being a more economical source of power than the Kananaskis Lakes and lending itself to faster development. Construction of this project was undertaken immediately and was followed by a logical sequence of development at Upper Kananaskis Lake, Barrier, Spray and the extension of existing plant at Kananaskis Falls — all as the economic development of the Province unfolded, the Company being finally successful in removing the obstacles to the Spray Development. These latter plants require no detailed description in this brief. They have been built in accordance with a carefully planned programme and their significant data can be obtained from Table No. 1, which lists the growth of the Company to date.

"Paralleling the expansion of the Company's generating facilities there has, of course, been a corresponding growth in the transmission and distribution network until today the system of the Calgary Power Ltd. extends over most of the southern part of the Province, not only supplying the needs of large urban centres but also bringing the advantages of low cost power to outlying districts. The present extent of the system is shown in Figures 3 and 4. Electric energy is sold in bulk to the cities of Calgary and Red Deer and the towns of Cardston, Macleod and Ponoka, as well as to some 169 industrial users of which the largest are the Alberta Nitrogen Products and the Canada Cement Company. Likewise the Company

retails electricity in the City of Wetaskiwin and in some 39 towns and villages, and it is significant to point out that before the Company entered this field such of the towns as had electric light systems were selling their energy at rates varying between 15 and 20 cents per k.w.h. whereas the present average price charged by the Company to its domestic consumers is 3.13 cents per k.w.h.

"Directly and through Farm Electric Services Ltd., a non-profit subsidiary of Calgary Power Ltd., some 11,000 farms are now electrified and this service continues to expand.

"Indicative of this vast expansion in the service of the Province is the fact that the Company's annual load is now over 700,000,000 k.w. hrs. whereas the annual load of ten years ago was less than 200,000,000 k.w.hrs."

Table 1

POWER AND STORAGE DEVELOPMENTS ON THE BOW RIVER

Date of Completion	Project	Head in Feet	Max. Turbine Discharge cfs.	Maximum Capacity in H.P. Project	Maximum Capacity in H.P. Cumulative	Storage in acre feet Project	Storage in acre feet Cumulative	Remarks
1891	Calgary Water Power Plant	12	80	780	780	0	0	Not controlled by C.P. Ltd. until 1928
1911	Horseshoe Plant	72	2,700	20,000	20,000	0	0	Pondage only
1912	Lake Minnewanka Storage				20,000	44,000	44,000	
1913	Kananaskis Plant	72	1,900	12,000	32,000	0	44,000	Pondage only
1929	Ghost Plant & Storage	110 - 75	3,700	37,450	69,450	75,000	119,000	
1932	Upper Kananaskis Lake Storage				69,450	36,000	155,000	
1942	Cascade Plant & Storage	345 - 330	800	23,000	92,450	180,000	291,000	Replaces 1912 development
1942	Upper Kananaskis Lake Storage				92,450	100,000	355,000	Replaces 1932 development
1947	Barrier Plant	155 - 120	1,100	16,000	108,450	20,000	375,000	
1951	Spray							
	(a) Storage				108,450	210,000	585,000	
	(b) Three Sisters Plant	65 - 25	800	3,600	112,050		585,000	
	(c) Spray Plant	900	800	62,000	174,050		585,000	
	(d) Rundle Plant	320	800	23,000	197,050		585,000	
1951	Kananaskis Plant Extension	72	1,800	12,000	209,050		585,000	Third unit added

"OPERATION OF CALGARY POWER PLANTS AND STORAGE ON THE BOW RIVER"

"Power progressive development of the Bow River for hydro-electric power as described in the preceding paragraph has resulted in a series of changes in the natural regimen of the stream. At the risk of over-simplification, these changes have been grouped into five phases:-

(1) Those following the construction of the Calgary Water Power Company hydro-electric plant and weir at Calgary in 1891 and 1894 respectively.

(2) Those following the construction by Calgary Power Ltd. of the Horseshoe and Kananaskis Falls plants in 1911 and 1913 respectively and the original storage on Lake Minnewanka in 1912.

(3) Those following the addition of the Ghost plant in 1929 and Upper Kananaskis Lake storage in 1932.

(4) Those following the addition of the Cascade development and the Upper Kananaskis Lake storage in 1942.

(5) Those following the addition of the three Spray plants and Spray storage in 1951.

"The record of regulated daily flows and of calculated natural weekly flows of the Bow River at Calgary is available from 1912 to date. These have been utilized on Figure 5 to plot the seven-day mean flows for the months of November, December and January and thereby illustrate the changing effect of storage during the last four phases.

"Figure 6 is a plotting of average daily flows at Calgary for the month of December in a typical year of each of the last four phases. On this graph has also been plotted the average daily temperatures to indicate the changing relationship between temperature and regulated flow.

"Figure 7 is a plotting of hourly flows at Ghost and at Calgary for a typical month in early winter to illustrate the cyclical patterns of the regulated flow of the river.

"The first phase of operation had no effect on the natural flow of the Bow above the Eau Claire weir. Moreover, the effect on flow below the weir was very slight. A canal conducted the water from above the weir to the power station some 3900 feet downstream, where the installation consisted of seven small turbines with total capacity of 780 h.p. capable of discharging about eighty c.f.s. under the installed head of twelve feet. Ice coming down the river jammed in the log channel above the weir and gave rise to much trouble in operation of the canal. The plant was entirely unreliable in winter and was frequently shut down for as long as several months at a time. It was taken over by Calgary Power Ltd. in 1928 and was operated for the last time in November 1929."

"In the second phase, beginning with the construction of the Horseshoe and Kananaskis plants and the first reservoir at Lake Minnewanka, some changes were introduced in the regimen of river flow reaching Calgary, but the total effect was still very slight, particularly in the earlier years. The Company operated a mere 44,000 acre feet of storage and hence had little control over the streamflow, the water being used more or less as it arrived at the plants. During this time the Company's principal loads consisted of the City of Calgary and the cement plant at Exshaw, and until 1924 neither of these caused much fluctuation in winter demand. Prior to 1924 the contract with Calgary was on a horsepower basis with the hydro plants at Seebe supplying base loads up to a specified maximum horsepower when water was available, and the steam plant at Victoria Park supplying the variable capacity to meet the peaks. The Cement Plant at Exshaw was closed down in wintertime and its power requirements fell to negligible proportions.

"Beginning in 1924 the new contract with Calgary called for supply of maximum possible energy from the Company's hydro plants with the deficiency to be made up from Victoria Park. This was followed by more efficient operation on the part of the Company and greater fluctuations in streamflow were introduced as load was proportioned between Horseshoe and Kananaskis in an endeavour to keep turbines loaded at point of best efficiency. Even so, it was not until 1927 that Horseshoe plant was shut down at night, and then only on rare occasions.

"In the third phase, after the introduction of the Ghost plant and the first storage on Upper Kananaskis Lake, there were two changes in operation that affected the regulation of the Bow. In the first place, the addition of 36,000 acre feet of storage at Upper Kananaskis raised winter flows slightly. (see Figure 5) The effect of the 75,000 acre feet of storage at Ghost plant was less noticeable, since this water was retained all during the winter, in order to keep up the head of the plant, and was then used quickly over a period of about three weeks immediately preceding the arrival of rising natural flows in the spring. In the second place, hourly variations in load were carried at Ghost Plant and caused fluctuations in river flow to be more noticeable in Calgary on account of the proximity of the plant to the City. Ghost plant is located 34 miles upstream of the city limits as compared with 49 miles in the case of Horseshoe, and the fluctuations reach Calgary with a lag of 8 to 11 hours for maxima and 11 to 15 hours for minima depending somewhat on the actual quantity of water flowing and the amount of ice in the river channel. This phenomenon is illustrated in Figure 7.

"The Ghost, moreover, has a greater capacity than Horseshoe and can discharge 3,700 c.f.s. as compared with 2,700 c.f.s. for the latter. This was a second factor tending to increase fluctuations noticed at Calgary, although it did not approach its maximum effect until the coming of war caused a sharp increase in the demand for power.

"It should also be pointed out that during this third phase there began a tendency to reverse the natural winter flow pattern of the river. In preceding years when cold weather arrived the flow of the Bow fell and the resulting shortage of hydro-electric energy at Horseshoe and Kananaskis plants was made up by steam plant generation in Calgary. After the addition of Ghost plant, however, such deficiencies were made up by increasing the generation at Ghost. Hence, periods of low temperature were likely to be followed by increased discharge of the Bow through Calgary. Conversely, during Chinook periods when the natural flow of the Bow River rose through Horseshoe and Kananaskis plants there was a tendency to reduce generation at Ghost and hence to discharge a smaller quantity of water through Calgary. It is difficult to determine the magnitude of this change since other influences such as the interconnection with other power systems also affected the pattern of the Company's load. The general effect, however, can be seen on Figure 6.

"In the fourth phase, with the addition of the Cascade plant and Upper Kananaskis storage in 1942, the storage operated by the Company above Seebe was increased from 84,000 acre feet to 280,000 acre feet and the winter flow of the Bow at Calgary was likewise raised. See Figure 5. The hourly fluctuations below Ghost followed the same pattern as established in the third phase but ~~the~~ are fluctuations were accentuated owing to the greater dependence on the system on Ghost plant for peak operation. See Figure 7. During the wintertime it was necessary to operate the Cascade, Horseshoe and Kananaskis plants at high load factor; the Cascade plant in order to withdraw the storage water from Lake Minnewanka for use in plants downstream, and the Horseshoe and Kananaskis plants in order to pass the increased flow of the river without wastage of water. This left the fluctuating of load demand to be carried principally by Ghost plant. It should be pointed out, however, that with increased generation of Ghost plant the number of hours of shut-down of the two large turbines was reduced.

"The fifth (and present) phase of hydro-electric operation on the Bow River differs from the fourth in that still more storage has been added upstream at the Spray development (and at the Barrier plant). The total storage above Seebe is now 510,000 acre feet and the regulated winter flow has again been raised. See Figure 5.

"It is to be noted, however, that this immense increase in storage above Seebe has not resulted in a proportionate rise in the regulated flow of the river. There are two reasons for this. In the first place, as storage is increased its effect in raising the level of regulated flows is reduced since it must be distributed over an increasingly longer period of the year. This can be confirmed by examining the hydrograph of Figure 2. and noting the greater length of the storage drawn-down period as the level of regulation flow is raised. In the second place the 210,000 acre feet of storage provided in the Spray Valley and the 180,000 acre feet of storage in Lake Minnewanka are a good deal more than can be replenished in a normal year.

"With the addition of 88,600 h.p. in the three Spray power plants the Company has excess generating capacity for the first time in ten years. Hence, during the past winter it has been possible to experiment with a uniform discharge through the Ghost plant while fluctuations in load were taken at the plants upstream. This, however, is a temporary condition and with the current rate of load growth it will be necessary in the winter of 1952-53 to carry a share of the variations in system load at Ghost plant. This will produce fluctuations of river flow in Calgary somewhat similar to those prevailing during the latter part of phase 4."

(f) Future Developments of the Bow River. Here again use has been made of the Calgary Power Ltd. brief:-

"Future Development of the Bow River"

"With the exception of the initial over-installation at Horseshoe and Kananaskis Falls sites in 1911 and 1913 due to lack of a reliable record of streamflows, the development of the Bow River to date has followed an orderly and well thought out plan to obtain maximum benefit from this great natural resource for the people of Alberta. First came the construction of the two power plants at the cheapest sites on the river at which a start could be made, Horseshoe and Kananaskis Falls. Then followed the development of storage at Lake Minnewanka, Ghost, Upper Kananaskis and Spray which has permitted progressively greater utilization of water by storing floods flows for use during the flow months of winter. Wherever feasible, the development of storage has been combined with power installations such as at Ghost, Cascade and Spray to take maximum advantage of the fall on the river, until the Company's total installed capacity has increased to 209,000 h.p. The creation of storage has, moreover, improved the power potential of the remainder of the river and rendered feasible the ultimate development of some 575,000 h.p. as shown in the tabulation below. In examining these figures it is interesting to recall that in the original estimate of power available on the Bow River published in Water Resources Paper No. 2 the power possibilities of the Spray, Cascade and Kananaskis valleys were overlooked and the total potential of the river given as 48,175 continuous h.p. or 96,350 h.p. at 50% load factor."

"ULTIMATE HYDRO-ELECTRIC DEVELOPMENT OF THE BOW RIVER".

Project	Head Feet	Proposed Capacity BHP	Storage Acre feet
Interlakes (Upper Kananaskis Lake)	100 to 76	4,500	0
Pocaterra	226	19,000	53,000
Lac des Arcs	65 to 32.5	17,000	130,000
Russell	141 to 101	78,000	78,000
Radnor	60	33,000	0
Glenbow	100	48,000	0
Bearspaw	66	25,000	0
Calgary Water Power Plant Reconstruction	24.5	9,000	0
Chestermere	47.5 to 38x	12,500	0
Shepard	300x	120,000	51,000
Total proposed capacity		366,000	312,000
Existing System		209,000	585,000
		575,000	897,000

x Subject to solution of ice problem in W.I.D. Canal.

"It will be noted in the above tabulation that relatively large capacities are planned for installation in the plants on the main river. Thus to obtain maximum utilization of water, using the extra capacity of the main river plants to take advantage of the high flows of summer while the storage plants of the Kananaskis, Spray, and Cascade Valleys are run at reduced load or closed down entirely to store water for the winter. The installations contemplated for the main river plants are also somewhat large since their locations relatively near the load centre will make it advantageous to use them to meet peak loads while obtaining k.w.hrs. from steam generation or long distance of hydro energy."

(g) Importance of Bow River Development to the people of Albert

From Section (e) which deals with the history of power developments and storage on the Bow River done by Calgary Power Ltd. it will be noted:-

(1) Before the creation of storage the original Horseshoe Falls power plant, constructed in 1911, was only capable of producing 2,500 h.p. or less during the winter months.

(2) By the successive development of storage works at Minnewanka, Kananaskis and Spray Lake, totalling some 585,000 acre feet, the power potential of the river has been increased by the installation of a total of 209,050 h.p. at eight plants. In addition, the creation of storage makes this water available at power site lower down the river so that an ultimate development of some 575,000 h.p. can be secured.

(3) One index of the prosperity of a country is the consumption of power. An indication of this expansion is evident from the fact that the Calgary Power Ltd. annual load has increased from 200 million k.w. hrs. less than ten years ago, to over 700 million k.w. hrs. at the present time.

Generally speaking, elsewhere in Canada, power development is less dependent on the construction of dams for artificial storage and as the natural flow of our great rivers do not have such a wide variation of summer to winter flow as compared with the Bow River, the cost of power development is, therefore, less. The ultimate development of the Bow River will consist of a number of comparatively small plants using storage water during the winter months in successive stages from Spray Lakes to the Prairie area, east of Calgary.

It is believed that, with few exceptions, such as Pocaterra and Shepard storage sites, the storage programme is almost completed. The whole is a well conceived engineering plan and if the Bow River had been left to its natural unregulated flow the whole of the industrial and domestic power outlook of Alberta would have been changed.

The engineering development has not been confined to water power alone, but this power has been distributed over a net-work of transmission lines to practically all cities and towns within an area extending over a large portion of the Province.

These lines are connected under exchange agreement with Canadian Utilities Limited, cities of Edmonton and Lethbridge, so that power may be made available one to the other (see Figures 3 and 4). This system is unique in as much as there are very few places where power in quantity is used and the average length of transmission lines to serve small users is greater than almost anywhere else. As Alberta becomes more industrialized this picture will, no doubt, be changed.

Power is supplied to many cities and small towns in Alberta at a price of about one-fifth that previously charged by local systems. Some 11,000 farms are now electrified and additional extensions are being installed each year. This work is being done at a cost price to the farmer under a non-profit subsidiary of Calgary Power Ltd.

Photographs Illustrating Typical Ice Pack Conditions

on the Bow In and Above Calgary

#6 Jan. 3, 1944. Bow at Bowness Bridge. Looking up river from bridge showing portion of ice pack two miles long lodged at bend one mile downstream.

#9 Jan. 5, 1944. Bow at Bowness Bridge. Looking downstream from bridge showing gorging on right bank from ice pack which moved out during the previous night.

#32 Jan. 2, 1945. Bow at Calgary. Looking upstream at western city limits showing pressure ridges and narrow open channel in relatively new ice pack.

6

9

32

IV WINTER FLOODS

Winter Floods, in general, were discussed briefly in paragraph (c) I and it was stated that winter flooding was due to ice conditions on streams. It is therefore pertinent to deal with this matter of ice under several headings, so that a knowledge may be gained as to the problem of confronting winter flooding in the Bow River Valley. These headings are as follows:-

(a) Formation of Ice;
(b) Theory of ice formation;
(c) Types of ice;
(d) Ice packs under static conditions;
(e) Ice packs under dynamic conditions;
(f) Cause of ice jams and backwater.

(a) Formation of Ice. The formation of ice in northern latitudes and elsewhere in high mountainous regions is the inevitable result of freezing air temperatures in contact with water. It is obvious, of course, that ice does not form in regions having a warm climate.

The natural phenomenon which causes ice to form on lakes, ponds and streams of flowing water, results by the transfer of heat by conduction and radiation from the water in contact with cold air having a temperature of 32°F. or less. The natural laws which govern the process of radiation are unique and complicated and in some respects are not, as yet, clearl understood.

In the past one hundred years ice formations have been the object of periodic interest but there has been little scientific investigation of the phenomenon. Early investigations were made in Canada by Professor H. T. Barnes of the Department of Physics at the University of McGill and

Photographs Illustrating Typical Ice Pack Conditions

On the Bow In and Above Calgary

#19 The Bow River at the curve above Shouldice Bridge at 2:24 p.m. on January 31, 1944. Looking upstream at moving slush ice passing a sharp bend in the river. Note the open water in the foreground between the moving slush and the near bank as the pack moves into an expanding section of the river.

#15 A photograph of typical slush ice sitting loosely in quiet water in the ice pack at Twin Bridges during the winter of 1943-44.

and reported by him in a text on "Ice Engineering". A study of the problem on the St. Lawrence River wasmade by the Montreal Flood Commission sixty-five years ago and more recently by the Joint Board of Engineering on St. Lawrence Deep Waterways. A report by Mr. J. C. Steven, Past President of the American Society of Civil Engineers, on the Madison River in Montana, a stream having similar characteristics to the Bow River, gives valuable information. Much laboratory work on the subject has been done in Russia. All of this data has been available to the Commission, but it is nevertheless apparent that detailed scientific research on the phenomenon of ice formation is still lacking.

In view of the importance of this subject to Canada, it is suggested that the National Research Council or the University of Alberta might do research work, especially on dynamic ice formation, as a valuable asset to Canadian industry and general welfare.

(b) Theory of Ice Formation. While certain deficiencies exist in knowledge of the phenomenon of ice formation in all its aspects, it is possible to describe the general features incidental to its development.

By physical examinations it is known that water, like other substances, will increase and decrease in volume through changes in temperature. As water cools it contracts to a small degree, becomes slightly heavier and sinks. This action continues until maximum density is reached at 39°F. At that point and with further decrease in temperature, a reverse condition occurs whereby water expands, becomes lighter and will rise. As a result of these conditions there is an inter-change of water from the surface to the

bottom and conversely from the bottom to the surface. This interchange is referred to as convection. This action continues until the temperature of water in a lake reaches 39°F. Thereafter with further decreased temperature, colder water will then remain at the surface.

By established theory a pound of water will gain or lose 1 B.T.U. (British Thermal Unit) for each degree change in temperature. Hence, for any given temperature above freezing, this theory applies until the temperature reaches 32°F. At this point a peculiar phenomenon occurs in the conversion of water to ice, whereby it is necessary for water to lose a further 144 B.T.U.'s to change to ice at the same temperature. This is referred to as the Latent Heat of Fusion of Ice. In actual effect a very slight difference of one to two one-hundredths degree (.01°- .02°) will result in the conversion of water to ice and conversely from ice back to water.

With continued cold air temperatures below 32°F. needlelike crystals of ice are formed. The needle-like crystals of ice knit and agglomerate together at the surface to form an ice cover. Once an ice cover is formed the further conduction and radiation of heat from water to air is checked but not entirely eliminated since ice, although a poor conductor, continues to transfer heat at a progressively reduced rate as the ice thickens until a state of insulation is obtained in relation to air temperature and no more ice is formed. It is fortunate, as a result of insulation, that flowing water will not freeze solid. If it did, life in it would cease.

Pure ice weighs approximately 571 lbs. per cubic foot as compared with water at approximately 62.5 lbs. per cubic foot. Hence all ice is buoyant and floats.

(c) Types of Ice. Ice which is formed on lakes, ponds and flowing streams of water is recognized under three types. They are classified as Sheet Ice, Frazil Ice and Anchor Ice. All have a common origin in the relation of temperatures and exposed water surface but differ in characteristics and appearance as a result of the environment of static or dynamic conditions in which they occur.

Sheet Ice forms under static conditions of still water in lakes and ponds and on the surface of flowing streams where the velocity of the current is not in excess of about 1.5 feet per second. The ice is firm, relatively clear and may attain a thickness up to 2.5 feet under the climatic conditions common to the region of the Bow River.

Frazil Ice. is formed under dynamic conditions of turbulent flowing water in which the ice particles are maintained in a state of agitation. The origin of the ice is the same as for Sheet or static ice in the transfer of heat from the ground through the water to the air, but in this case the flow of heat through the water is radically affected by the turbulent water and instead of having a falling temperature gradient by convection as in the case of Sheet Ice, water temperatures are rapidly mixed to temperature of 32°F throughout. Some authorities claim that all ice crystals are produced at the water surface. Others claim the crystals are formed throughout the body of the water at 32°F. Frazil ice is buoyant and agglomerates into soft sponge masses to float barely awash in uniformly swift flowing water. These masses disintegrate over falls and rapids and re-form again at the water surface in quieter water.

Anchor Ice is a tough laminated ice which forms at the bed of a turbulent stream. There appears to be no definite theory to explain the reason for its existence at this place. One theory is that turbulent water carries a portion of the frazil ice to the bottom of the river where it adheres to gravel, stones and other firm substances. Other authorities appear to dispute this theory.

It is sufficient for the purpose of this report to describe general conditions.

Dark or black colour of the stream bed appears to be conducive to the growth of Anchor Ice.

Observations indicate that Anchor Ice is formed in greatest quantity during clear cold nights. In highly turbulent water it may attain such thickness as to raise the water in a river bed several feet. It has been found on the St. Lawrence River under 20 feet depth of water and under a depth of 65 feet in the Neva River in Russia.

Anchor ice will remain intact at the river bed until released by radiation from the sun whence it will rise and float to the surface in masses observed on the Bow River of 100 square feet or more. Upon being detached from the river bed, it will lift sand, gravel and rocks of considerable size and is generally dirty in appearance. Upon rising it joins the Frazil ice which together float downstream. This combined accumulation of ice is referred to as Slush.

See Photos Nos. 15, 161, 170, 171 showing types of ice formations and slush.

Slush - The volume of Slush which may occur in a flowing stream will vary with the relative changes in degree days of freezing temperature

Photographs Illustrating Typical Ice Pack Conditions

On the Bow In and Above Calgary

Three photographs illustrating the growth of an ice pack:

#170 Looking downstream at Shouldice Bridge Dec. 2, 1946, from the east river bank, showing thin slush masses at the head of the pack.

#171 Looking downstream at Shouldice Bridge Dec. 3, 1946, from the east river bank, showing the very slow buildup of the pack due to mild weather. Moving ice is entering the pack in the right foreground.

#173 Looking downstream at Shouldice Bridge Dec. 4, 1946, showing some consolidation of the pack from the previous day. The stage of the river had risen considerably from that in #170.


171

Photographs Illustrating Typical Ice Pack Conditions

On the Bow In and Above Calgary

#161 Looking upstream at Louise Bridge from the north river bank on November 21, 1946. This section of fairly smooth pack is sitting under high backwater nearly level with the river bank. Note gorging line along near shore.

#165 Looking up the Bow at 31st St. West on November 26, 1946, showing extremely rough, telescoped pack under high backwater conditions. A pressure ridge, indicating the toe of a movement can be seen in the middle of the picture.


164


165

and the exposed areas of flowing water having velocities in excess of about 1.5 feet per second which cannot be covered with Sheet ice. The volume of slush is continually increased by accretions of newly formed ice as the open water moves downstream and is decreased by the consequent reduction of surface area brought about by ice cover.

To illustrate:- Assume a pond from which water emerges at temperatures above freezing:- As the flowing water from the pond in contact with cold air attains a temperature slightly less than 32° F., ice begins to form. From this point on, for each succeeding unit of distance downstream, more ice is formed in the open flowing water. The water is, therefore, increasingly loaded with ice until in fact it may resemble a viscous sluggish fluid. In this movement downstream the flow of ice-laden water lodges the slush along the shores of the river. Thus the stream is relieved of a part of its ice burden, the area of exposed water surface in contact with cold air is reduced and less new ice is formed, for neither Frazil or Anchor ice can be formed under an ice cover. A continual change is brought about in the area of ice forming openwater. These changes of area in relation to the degrees of frost required to produce ice, make the problem of determining the volume of ice very problematical.

It is interesting to note, however, that by experiments conducted on the St. Lawrence River it was determined that ice is produced by the radiation of approximately 95 B.T.U.'s per square foot per day per degree difference in temperature between the air and water. Upon dividing this product by 144 to provide for the latent heat required to produce a pound of ice at 32°F. and by 57 lbs. to convert to cubic feet, it is possible to determine the volume of ice capable of production on one square foot of

exposed open water. For example:- assume that an open area of water at a riffle where velocities preclude an ice cover, is subject to 2500° days of frost as occurred along the Bow River during the winter of 1949-50, then the volume of ice produced would be equivalent to 30 cubic feet per square foot of exposed area.

It is fortunate, indeed, that the area of open water is decreased by the ice cover, otherwise vast quantities of ice would be formed. The formula illustrates, however, that a short period of very cold weather at the outset of winter rather than a prolonged period of less cold days with intervening Chinooks, would be more effective in quickly producing an ice cover, except at rapids, and thereby eliminate much ice formation.

(d) Ice Packs Under Static Conditions. Reference has been made to the formation of slush and to its movement downstream at the water surface in a sluggish and viscous mass. It is intercepted along the rough shores of the river channel, by gravel and sand bars and at points of shallow depth of water and low velocity where it begins to lodge along the banks to form an ice cover. If the stream velocity does not exceed 1.5 feet per second, the cover will gradually grow toward the centre until a complete sheet of ice is formed. Through lack of disturbance the ice is clear particularly at the surface due to overflows of water, but it may contain ice of cloudy appearance due to small quantities of saturated slush formed at some point along the river where the velocity of water exceeded 1.5 feet per second.

In the latitude of the Bow River sheet ice cover may attain a thickness up to 2.5 feet. It remains intact throughout the winter until broken up in large blocks by warm spring weather and the concurrent inflow of water from melting snow when it moves downstream and gradually disappears. At times, in

the event of pronounced spring thaws and rapid rise of river flow, the blocks of ice may be intercepted by some obstacle resulting in severe ice jams to cause overflow of land and damage as occurred on the Saskatchewan River at Medicine Hat in 1951 and again in 1952 to wash out the Saskatchewan Bridge.

(e) Ice Packs Under Dynamic Conditions. Ice packs and ice jams on the Bow River in the vicinity of Calgary differ in the fact, primarily, that they occur in the early winter during November or December and seldom after January 1st when severe winter weather usually starts. The reason for this is due to the steep river gradient and velocity of water generally in excess of 1.5 feet per second thereby precluding the formation of Sheet Ice but forming large volumes of Frazil and Anchor Ice to flow as slush. Slush, as hereinbefore described, moves in a viscous sluggish mass downstream and may be intercepted by various obstacles. These obstacles are numerous of which the first to be mentioned is the continually changing conditions of the shore line against which the slush is brought in contact with rough rocky shores, sand and gravel bars, islands and the roots and overhanging branches of vegetable growth. This is continued along the whole length of the shore on which large quantities of slush are attached along the borders of the channel, termed for convenience as "Bord Ice". This is illustrated by photograph No. 121. The "Bord Ice " grows toward the centre of the river but at some point is stopped by the increasing velocity of the flowing stream. The remaining ice laden water continues to flow until it is stopped frontally by some physical obstacle. Of these, the one most effective obstacle appears to be a pool existing naturally or created artificially, such as deepening the river bed or by a dam to cause slack water and the early formation of an ice cover. Slush arriving at the head of the slack water loses

Photographs Illustrating Typical Ice Pack Conditions

on the Bow In and Above Calgary

#35 Jan. 5, 1945 - 2:15 p.m. Bow near Glenbow. Looking upstream opposite Glenbow station showing extent of gorging to date (18 miles below Ghost).

#119 Feb. 4. The C.L. & I. Company dam at Carseland from the south shore.

#121 Feb. 4. Looking down the Bow from the Carseland Bridge. Side board ice does not seem to be greatly affected by stream fluctuation.

35

119

121

velocity and starts to form an ice dam. This becomes the head of an Ice Pack. As further slush arrives, part of it is intercepted at the head of the pack which progressively advances upstream. The head of a pack produces an increase in the height of water causing backwater and may overflow low lying ground along the river channel. If velocities of the river current do not exceed approximatel 2.5 feet per second, most of the slush will adhere to the head of the pack while a part may be drawn underneath. Ice going under the head of a pack may flow for some distance or attach itself to the bottom of a pack and at some points produces hanging dams. An ice pack may advance upstream several miles per day depending on the surface area of open water and temperature conditions. Thus in a stream having velocities in excess of 1.5 feet per second an ice cover is formed by the advancing ice pack filling in the space between the "Bord Ice" along the banks of the river channel except at falls and rapids.

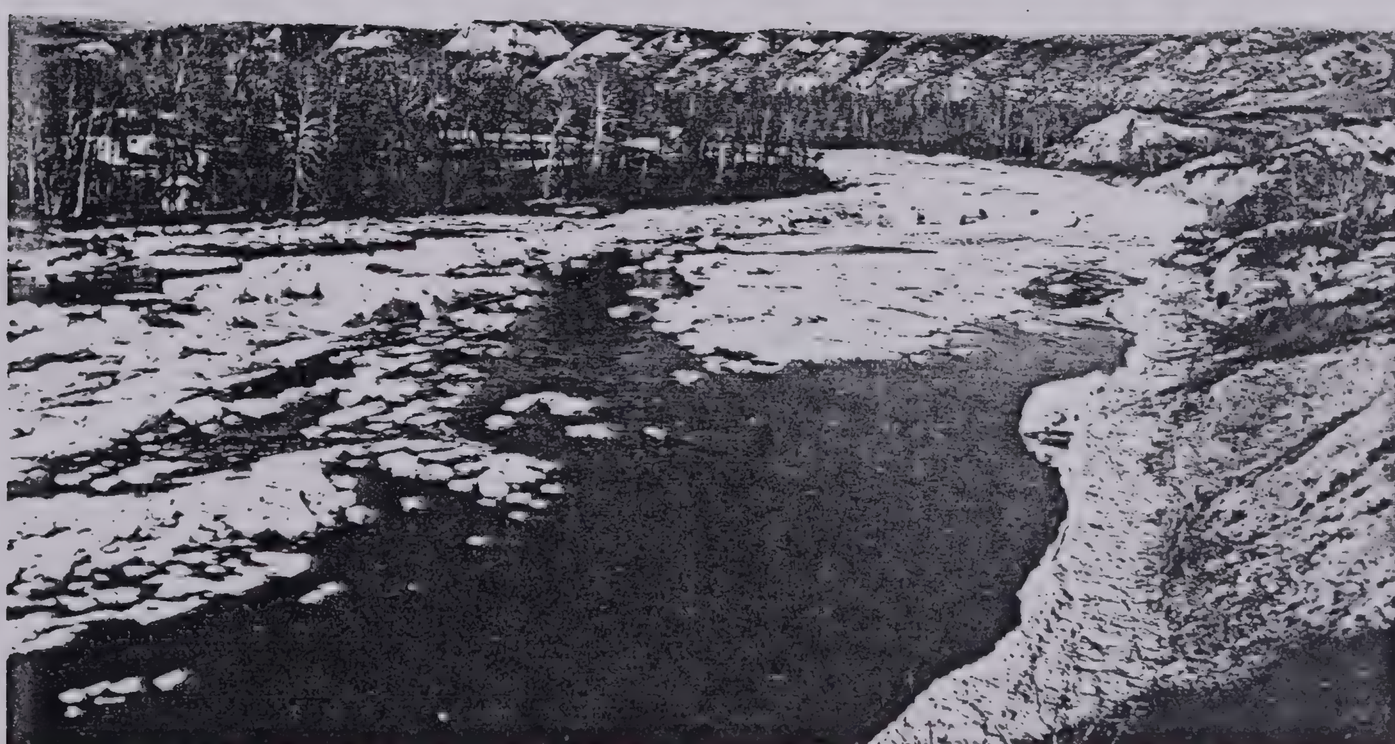
(f) Cause of Ice Jams and Backwater. In a stream such as the Bow River at and above Calgary, variations occur in the natural conditions of the river channel and a variety of different obstacles. Some of these obstacles such as a pool are relatively positive in their action to form the head of an ice pack. Other obstacles such as bridges, a narrow section, an island and other conditions along the river are less positive in their action to form a permanent head of a pack. At these points incipient heads of packs may be formed in their relative order of active obstruction. In every case backwater occurs which creates a pressure head whence the weakest of the incipient packs may be broken up and washed downstream to a more permanent pack which in turn, under still higher backwater, may go through a similar procedure to another pack. This results in telescoping one pack into another according to their relative stability, and each in turn may result in backwater

of greater magnitude. The process of telescoping from one incipient pack to another clears the centre of the river channel resulting in "gorging" leaving open water for further ice formation and large quantities of ice along the river shores. (see Photo 544).

The telescoping from one incipient pack to another may, however, result in pronounced ridges at the surface of the pack and probably to some depth below the pack thus creating further obstruction until the force of water finds a way through. (see Photo 165)

These conditions on the Bow River at and near Calgary may prevail during the pack formation period usually November and December or until severe winter conditions in January set in to stabilize the final ice cover. The ice pack is then completed thereby reducing the areas of open water except at falls or rapids and little new ice is formed. Water finds a way by cavernous channels called "bores" through the pack until the pack is melted in the spring.

As stated previously the formation of an ice pack when more or less consolidated across the river is accompanied by high backwater. Figure 14 is a "Profile of Bow River and Observed Backwater Stages from Horseshoe to Morley Winter of 1951-52." From this it will be observed that the average height of backwater is about 5 feet, while at the Russell Site the backwater reached a height of 12½ feet or as high as any winter backwater ever recorded in the Calgary district. Notwithstanding this high backwater flooding was not reported, although no doubt it occurred at places, but no damage was done on account of there being no buildings or inhabitants in that location.



1.

Photographs Illustrating Typical Ice Pack Conditions

On the Bow In and Above Calgary

#544 Looking down the north channel at St. Georges's Island at the north traffic bridge on November 24, 1950. The high, gorged ice banks here are the evidence remaining of a tremendous ice movement down this channel during the previous night.

#1 Dec. 29, 1943 - 3:15 p.m. Bow River above Shouldice Bridge. Looking upstream at slush, showing slush temporarily lodged in curve above bridge.

Photographs Illustrating Typical Ice Pack Conditions

On the Bow In and Above Calgary

#2 Dec. 29, 1943. Bow above Shouldice Bridge. Looking up-stream from hillside at bend above bridge showing temporary lodgment occurring on low flow.

#5 Monday, Jan. 3, 1944. Bow at city limits. Looking up north channel at head of island above city limits showing anchor ice on river bottom. Low flow on river (2.00 p.m.)

2

5

Figure 11 shows the maximum observed backwater stages on the Bow River from Cushing Bridge (Calgary) to Bowness Bridge 1947-51. The significant things to be noted in respect to Figure 11 are as follows:-

(a) There are many places on this stretch of river, where the ice lodges and ice packs are formed, although all are not formed simultaneously. The points of lodgment are indicated by low backwater followed by high backwater immediately upstream.

(b) The gravel excavation below Cushing Bridge; (Jeffrey Pool) the W.I. D. dam; south bridge to St. George's Island; the head of St. George's island in the vicinity of Louise Bridge, the Eau Claire weir prior to its being largely removed in 1946 and 1950, a point near the Shouldice Bridge; all are major points for the start of ice packs.

Just as there are many points recorded at Calgary and west of Calgary, even to beyond the Ghost Dam, where ice packs are formed, there may be points between Calgary and Carsland dam where similar conditions exist for the formation of ice packs.

One thing is certain that the Carsland dam constructed in 1910 in conjunction with the island and river conditions of that locality, acts as a positive ice trap from which a pack builds upstream.

Having discussed, briefly, the ice factors and conditions in relation to high backwater, which may cause flooding, it is pertinent to apply this information to the specific problem viz:- Winter flooding on the Bow River under natural flow as contrasted with winter flooding as a result of increased winter flow due to storage reservoirs constructed in the head-waters of the Bow River by Calgary Power Ltd. This is section (a) and (b) of part one of the "terms of reference".

V WINTER FLOODS ON THE BOW RIVER

(1) Winter Regime Under Natural Flow. The history of winter flooding on the Bow River is naturally incomplete because of the valley having been only sparsely built on until comparatively recent times. There is evidence to show that the formation of ice packs has always been a winter phenomenon of this river. Appendix "A" "History and Description of Ice Jamming and Flooding on the Bow River at and about Calgary" is attached.

Figure 15 "Chart on Mean Monthly Flows, Bow River at Calgary and occasions of Recorded Winter Flooding" and Figure 5.

In examining Appendix "A" and Figures 5 and 15, it is important to note that while storage dates from the completion of the Lake Minnewanka, 44,000 acre feet storage for 1912, this was supplemented by the Ghost storage of 75,000 acre feet in 1926 when the total storage amounted to 119,000 acre feet (See page 1 and part 1 - Table 1.).

Since that date the following storages have been created,-

1932 - Upper Kananaskis Lake	- 36,000 acre feet
1942 - Lake Minnewanka a*	- 180,000 acre feet
1942 - Upper Kananaskis Lake b*	- 100,000 acre feet
1947 - Barrier	- 20,000 acre feet
1951 - Spray Lake	- 210,000 acre feet
Total since 1932	- 546,000 acre feet

a* Replaces 44,000 acre feet created in 1912.
b* Replaces 36,000 acre feet created in 1932.

The total storage to date being 585,000 acre feet.

This is sufficient water to augment the natural flow of the Bow River during the winter months by an average of 2,200 cubic feet per second (c.f.s). The Ghost plant is the last one down the river and therefore nearest to Calgary, being some forty miles west of that City.

All storage water used must necessarily pass through the Ghost plant supplemented by the natural flow above that point. The Ghost plant has a smaller head than most of the other plants, and in order to conserve, water is used as a peak load plant to iron out the fluctuations of the load and build up a storage on the off-peak periods. In this way anything that happens down stream in the way of flow is determined by the operations of the Ghost plant and from the very nature of its operations the result is a fluctuating flow varying from 3,700 c.f.s on peak loads to a minimum of 150 c.f.s. This is an entirely different regime of the river than had existed prior to the construction of this plant in 1929.

While 44,000 acre feet of storage was developed at Minnewanka prior to this date it had little effect on the natural winter flow of the Bow River. Winter floods have been known to occur on the Bow River as early as 1893 and since 1896 ice jamming has been recorded for twelve years out of sixteen years until 1911. From November, December and January 1910-11 to the same period 1929-30 winter flooding occurred in Calgary district in six of the nineteen years. Since 1929-30 until 1951-52 winter flooding has occurred in fourteen of the years out of the twenty-three years (See Figure 15).

It would appear that after the advent of storage at Ghost reservoir winter floods are increasing in number, although not necessarily in intensity as just as high backwaters were created under winter flooding under the natural flow of the Bow River as under present conditions.

By reference to gauge height at Langevin Bridge it is possible to compare the levels of these recent winter floods with former spring floods,-

Date	Maximum Gauge Height	
	Winter Flood	Spring Flood
June, 1897		17.52 feet
July, 1902		16.70 feet
Dec. 1, 1950	15.3 feet	
Dec.19, 1951	13.4 feet	
June 3, 1932		12.50 feet
Jan. 14, 1948	12.1 feet	
Dec. 16, 1949	10.9 feet	

While winter floods have increased in number since the construction of the Ghost plant in 1929, it is worthy of note that there has been an increase in the severity of the winter, especially during the last ten years. This may in some measure account for the frequency of winter flooding as temperature is the primary factor in the formation of ice and ice jamming.

The following table shows the degree days for the period 1926 to 1952.-

Table 3

TEMPERATURE DATA AT CALGARY
Based on Gas Company Records
Degree-Days below 32° F.

Year	Start of Period	Degree-Days to Dec. 15	Degree-Days to Feb. 28	Degree-Days Mar. 1 to end	Date of end of period
1926-27	Nov. 16	620.8	1,742.2	117.3	Mar. 31
1927-28	Oct. 31	953.5	814.3	-8.8	Mar. 16
1928-29	Oct. 27	22.8	1,152.5	-111.7	Mar. 31
1929-30	Oct. 29	264.9	1,393.3	118.1	Mar. 29
1930-31	Oct. 15	7.1	77.6	191.4	Mar. 28
1931-32	Nov. 9	380.2	1,293.6	365.9	Mar. 30
1932-33	Oct. 27	326.6	1,192.6	133.3	Mar. 26
1933-34	Oct. 19	100.3	756.9	29.2	Mar. 29
1934-35	Nov. 17	17.4	1,055.6	230.8	Mar. 31
1935-36	Oct. 28	269.4	2,244.1	190.8	Mar. 31
1936-37	Oct. 31	-10.5	1,608.3	91.9	Mar. 31
1937-38	Nov. 10	435.7	1,519.1	-8.1	Mar. 31
1938-39	Nov. 4	83.8	1,177.3	232.7	Mar. 26
1939-40	Oct. 23	-303.1	827.6	89.6	Mar. 27
1940-41	Nov. 2	434.9	1,155.2	164.6	Mar. 17
1941-42	Nov. 17	91.1	831.5	10.0	Mar. 28
1942-43	Oct. 24	418.8	731.6	383.3	Mar. 21
1943-44	Oct. 23	-184.0	309.3	242.5	Mar. 28
1944-45	Nov. 1	24.2	892.1	112.4	Mar. 8
1945-46	Nov. 5	480.5	1,148.8	-12.2	Mar. 9
1946-47	Nov. 14	499.8	1,411.9	331.2	Mar. 12
1947-48	Nov. 4	304.2	1,137.7	329.0	Mar. 26
1948-49	Dec. 3	400.4	1,919.9	151.5	Mar. 20
1949-50	Dec. 3	192.8	2,285.7	255.0	Mar. 20
1950-51	Nov. 7	574.1	1,696.9	560.4	Mar. 20
1951-52	Oct. 15	323.9	1,837.9	324.8	Mar. 22

Before storage works were constructed on the Bow River the winter flow varied over fairly wide limits, depending on temperature conditions.

For example, take the year 1936, the natural flow in the third week of December was 1,200 c.f.s. and in the fourth week of the same month it was 300 c.f.s. Similarly in respect to other years during extremes of continued cold weather, the flow was curtailed and a large portion of the water was converted into bord and sheet ice. This would have a beneficial effect in preventing the formation of frazil and anchor ice. On the other hand when the temperature moderated and chinooks occurred some of the ice melted which, together with the increased run-off, caused a rise in the flow of the river. This increased flow and open water would break up the bord and sheet ice and carry it down the river. In general, mild weather due to chinooks only lasts a short time to be followed by cold weather.

When cold weather occurs frazil and anchor ice are formed from the open water due to the incceased flow. This frazil and anchor ice together with the bord and sheet ice formed during the low stage of the river may become lodged at many points to form ice packs with attendant high backwaters. Under these conditions flooding has occurred in the Calgary - Bowness area.

It is a fair assumption and no doubt a fact as shown by the evidence of several witnesses that this has been the condition of the river at times when skating was done on the river in the vicinity of Calgary.

Table 2 is a record of winter flooding under natural flow conditions,-

Table 2

RECORD OF ICE JAMMING AND WINTER FLOODING ON THE BOW RIVER AT CALGARY

Winter	Date	Location	Source of Information
1893-94	Thanksgiving	Eau Claire Dam	Theodore Strom
1897-98		West Calgary	J. Lawrey and P.A. Prince
1898-99		West Calgary	J. Lawrey and P.A. Prince
1899-1900	December	West Calgary	J. Lawrey and P.A. Prince
1903-04	Nov. - Dec.	West Calgary	Calgary Herald
1913-14	Dec. - Jan.	Eau Claire Dam to Bowness	Calgary Herald and Riverside Lumber Co. vs. Calgary Water Power Company
1914-15	Nov. 21-27	Upstream from Eau Claire Weir	Riverside Lumber Company vs. Calgary Water Power Company
1916-17	Nov. 18	Upstream from Eau Claire Weir	Calgary Herald
1926-27	Nov. 22	" " " "	Calgary Herald
1927-28	Nov. 16	Sunnyside, Westmount, Lowery Gardens	Calgary Herald and Water Power and Reclamation Service.
*1929-30		Lowery Gardens	Calgary Albertan
1932-33	Dec. 9	St. George's Island and Lowery Gardens	Permanent Flood Committee
1935-36	Dec. 14	St. George's Island	Calgary Herald
1937-38	Nov. 29	Imperial Oil Warehouses Lovell's Dairy	Permanent Flood Committee
1938-39	Dec. 20	Lowery Gardens	Calgary Herald and Calgary Albertan
1939-40		Lowery Gardens	Calgary Albertan
1940-41	Nov.-Dec.	Lowery Gardens	Calgary Alberta and Calgary Herald
1941-42	Dec. 29	Sunnyside	Permanent Flood Committee
1942-43	Dec.-Jan.	Calgary,Lowery Gardens Bowness	Calgary Herald and Permanent Flood Committee

* Ghost plant constructed

Table 2 cont'd

Winter	Date	Location	Source of Information
1943-44	January	Lowery Gardens and Bowness	Calgary Power Ltd. and Permanent Flood Committee
1945-46	Nov.-Dec.	Hillhurst, River Drive and Bowness	Calgary Power Ltd. and Permanent Flood Committee
1946-47	Nov.-Jan.	St. George's Island, Elbow River, Shouldice, Bowness Central Alberta Sanitarium, Alberta Ice Co.	Calgary Power Ltd. and Permanent Flood Committee
1947-48	Jan.-Feb.	Memorial Drive, Elbow River Sunnyside, Lowery Gardens	Calgary Power Ltd. and Permanent Flood Committee
1948-49	December	Memorial Drive	Calgary Power Ltd. and Permanent Flood Committee
1950-51	Nov.-Dec.	East Calgary, Riverside and Sunnyside	Calgary Power Ltd. and Permanent Flood Committee
1951-52	Dec.-Jan.	Lowery Gardens, Bowness Seepage in Sunnyside	Calgary Power Ltd. and Permanent Flood Committee

(2) Effect of Higher Flow due to Storage on Winter Regime. Figure 5 is a Hydrograph of Average Weekly Flows of the Bow River at Calgary. The heavy black column shows the number of c.f.s. of storage water while the hatched column shows the number of c.f.s. of natural flow. The two together represent the discharge at Calgary.

It is evident that the total winter flow has increased greatly, especially since 1942-43, and now that Spray Lakes storage is completed it will increase annually depending on winter power load requirements.

This increase in winter flow has naturally changed the whole regime of the river as compared with natural flow. In 1951-52 the maximum weekly flow averaged a little over 3,000 c.f.s. during the week of October 29 - November 5, while the minimum flow averaged a little over 2,000 c.f.s. for the week ending January 28th.

The problem is what effect does this increased winter flow have in respect to flooding in the Calgary - Bowness area.

A river flowing freely can take care of increased flow by increasing its depth, width and the average velocity.

Applying these to winter conditions on the Bow River the increase in flow may appear to increase the ice forming factors that may cause ice jamming and flooding. It does not necessarily mean that increased flow will increase the surface width of the river due to the steepening of the river banks by the formation of bord ice and the shearing of ice pack and the formation of gorges. It is doubtful under these conditions if the width of the river is greatly increased to take care of the higher flow. On the other hand the increased velocity of the water will tend to restrict the amount of bord ice formed along the edges of the river and increase the amount of frazil ice. The increased velocity increases the transporting power so that slush ice will be carried farther downstream before an ice bridge can be formed, and may thus delay the critical date when an ice pack would normally begin. Again under higher flow there is less chance of ice lodgment at points to form incipient ice jams.

The beneficial effects of the storage dams at Barrier and Ghost which eliminate ice formed over some fifty miles of river is discussed further in this report. Under natural flow ice stopped by these dams would be transported through Calgary if not intercepted by ice packs somewhere along the river. In view of the many imponderables, it is difficult to say whether the increased winter flow results in a more serious flooding condition than that previously existing under natural flow. As floods

occurred under both conditions of flow the real problem still remains to be solved, namely, "How can winter flooding be prevented or reduced to such an extent as to eliminate danger to life and property?".

(3) Effect of Variable Flow. Variable flow is caused by using the Ghost Plant for peak load operations. The two large turbines are used to take care of peaks while the small unit using 150 c.f.s. is operated when the large units are shut down. The large units are started about 7 a.m. and their loading increased continuously to about 9 a.m. to meet the morning peak demand. Discharge would thus rise from a minimum of 150 c.f.s. at night to a maximum of some 3,700 c.f.s. under the morning load conditions. During winter, this rapid rise of discharge arrives at Calgary about 5 p.m. as a wave on which much slush ice had been accumulated. It was an unusual sight and it was natural that popular opinion should associate it with ice jamming phenomenon.

As the Permanent Flood Committee has given this matter much study the following is taken from their Report of January, 1952, in respect to uniform flow,-

"The attached chart No. 1 shows the flows in effect from the Ghost plant from December 1st, 1951 to January 24th, 1952. Recorded air temperatures in Calgary are also shown on this chart.

"Uniform flow was made operative December 6th at a rate of 2,800 c.f.s. On December 9th, owing to mild weather uniform flow was discontinued temporarily. On December 13th a uniform flow was re-established and a rate of 3,000 c.f.s. maintained until December 22nd.

"On December 22nd the uniform flow of 3,000 c.f.s. was reduced to 2,200 c.f.s which flow was maintained until January 25th, 1925, by which time the ice pack had built upstream to Cochrane."

"The general observation of the Committee is that uniform flow did not result in improved conditions through Calgary. Two rates of uniform flow were tried and during both these trial periods ice conditions

and backwater stages were very similar. When the uniform flow was reduced on December 22, 1951 the head of the ice pack was approaching the City limits. Plate 5 shows the maximum backwater stages each winter from 1947 to 1951 at various points between the Cushing Bridge and Bowness Bridge. The backwaters resulting from the uniform flows of 1951-52 were as high as the backwater stages observed during the fluctuating flows of previous years.

"During the past few years it was considered that the ice gorging and telescoping which occurred during daily fluctuating flows contributed to ice jamming. In eliminating the daily fluctuating flows it was considered a high uniform flow would tend to resist ice lodging within the City. Under conditions of uniform flow there was not as much indication of telescoping and gorging but the ice pack built up as fast as in previous years. Telescoping however did occur at Bowness. The density of the ice pack does not appear to be much different from previous years and the resulting backwater stages have been equally high.

"In connection with the study of conditions under uniform flow the attached statement in the appendix submitted by the Department of Resources and Development together with plates 1, 1a and 2 contribute pertinent data in this connection. The information supplied by this Department points out that there is a storage of water created by the formation of anchor ice. The formation and release of anchor ice causes natural fluctuations in the flow even with a uniform discharge from the Ghost Reservoir. Although these fluctuations are not large they explain the variations in flow that have been commented on by nearby residents along the river.

"Plates 3 and 4 attached hereto in the appendix show the mean monthly averages of the river flow from 1911 to 1951. Plate 4 indicates an increase in the general average winter flows during the past ten years with the highest average occuring during the uniform flow period of 1951-52. It is difficult to estimate what effect the increased flow of water has had on ice formation.

"River studies to the present time have not established that uniform flows are more advantageous than fluctuating flows, but it is the concensus of the Committee that high minimum flows would be preferable to the low minimum flows of the past years.".

The Commission is bound to give this Report great weight and it will be noted that the concensus of opinion of the Committee is "that high minimum flows would be preferable to the low minimum flows of the past years".

VI PERMANENT FLOOD COMMITTEE

The recurring winter flooding between the Cushing Bridge and Bowness has been the subject of much study in recent years. A Committee of prominent engineers representing the Provincial Government, the Federal Government, Calgary Power Ltd., and the City of Calgary was formed on the initiative of the City in 1945 and has continued to function since that time, becoming a permanent committee in January, 1951. The members of this committee are to be commended for the evidence they have accumulated and the objective manner in which it has been presented. In their endeavors to find a solution they have considered dyking, dredging, maintenance of uniform flow, the construction of a catchment basin at Bearspaw, and various other proposals. Some of these measures have already been tried, either in whole or in part, and while the complete solution to the problem has not yet been found, worthwhile advance in knowledge and experience has been gained. Report of this Committee, January, 1952 is attached (See appendix "B").

VII REMEDIAL WORKS AND RECOMMENDATIONS

In a turbulent river such as the Bow, subject to low temperature conditions in the winter months, ice forming factors are large, therefore conditions are such that the problem of ice control so as to prevent flooding in settled areas will always be present.

The variable nature of the river bed of the Bow River with riffles, bends, gravel bars and islands also tends to produce incipient points of lodgment for the creation of ice jams and high backwaters that may cause winter floods. An ideal river is one that has a low gradient and

a flow of some 1.5 feet per second or less. Under these conditions the surface of the river becomes completely covered with an ice sheet thus preventing the formation of frazil and anchor ice.

It is evident from the above, that since we have this problem of ice conditions on the Bow River, remedial measures are necessary in order to prevent flooding in the Calgary - Bowness area. The means of control must, necessarily, be by man-made works located at strategic points, and will be referred to as dams or ice traps.

(a) Ice Traps. The purpose of an ice trap is to partially dam the river so as to create still water on the upstream side. This allows sheet ice to form rapidly and by collecting slush ice the beginning of an ice pack is soon made. Under cold weather conditions the pack grows rapidly upstream with attendant high backwaters at the head of a pack but on the downstream side, the river is left ice-free as a positive ice trap does not permit of the passage of ice downstream.

From the above it is evident that apart from being positive in character to trap the ice, the location is a most important consideration because all the benefit is downstream while upstream high backwaters may be expected and winter flooding may occur.

(b) Dams or Storage Reservoirs. Reservoirs, dams and fore bays used in connection with power development on the Bow River act as definite and beneficial ice traps. For example Minnewanka reservoir, Barrier Dam, Kananaskis and Horseshoe developments and the Ghost dam.

BARRIER DAM Although power is developed at this site it was constructed especially to eliminate slush ice which interfered with the

operation of the Kananaskis and Horseshoe power plants which had only small fore bays on the Bow River. The effect of the Barrier Dam is to eliminate the ice formed from some thirty-five miles of the Kananaskis, a turbulent river, before it enters the Bow River at Seebe.

GHOST RESERVOIR The Ghost reservoir having 75,000 acre feet of storage not only acts as an efficient ice-trap to eliminate the passage of ice, but on account of its size the water, under the ice-sheet of the reservoir, is actually heated in its passage and leaves the reservoir at a temperature of some one-half to two degrees above freezing. The manner in which this heat is transferred to the water is not clearly understood. (See exhibit 81 showing water temperatures in Ghost reservoir, December 21, 1944).

The result of these conditions is to eliminate ice forming conditions for some distance downstream from the Ghost Dam. This distance is dependent on the severity of the weather and varies from two and one-half to nineteen miles.

From the above it is evident that the Ghost Dam has a very beneficial effect on ice conditions downstream. However, as the Ghost Dam is some forty miles upstream from Calgary it cannot protect more than fifty per cent of the conditions in the river. It is therefore necessary to provide additional means to prevent flooding in the Calgary - Bowness area.

Apart from incipient points that trap ice due to lodgment in the intervening stretch of the river and beyond, there were at least three points in the vicinity of Calgary that formed definite ice traps viz,- Eau Claire weir, Jeffrey's Pool and Carsland Dam.

EAU CLAIRE WEIR As early as 1893-94 ice jamming and winter flooding at Calgary was noted as a result of high backwater caused by an ice pack building up from the Eau Claire weir. Since that time, up to 1946, when the weir was removed, flooding upstream was more or less of common occurrence. Since 1946 lodgment has been transferred further downstream and an icepack starts at the still water formed by the gravel excavation at Jeffrey's Pool and advances upstream with the W.I.D. dam as a key.

The high resulting backwaters may cause flooding in east Calgary and aggravate the seepage problem upstream.

The evidence presented to the Commission was practically unanimous to the effect that a major ice-trap such as a dam, with or without power development at Bearspaw would go a long way towards solving the problem of winter flooding in the Calgary - Bowness area. In this connection, however, other man-made works may be found to be necessary in order to provide for further protection in the area below Bearspaw.

(c) Bearspaw Power Development. An ice trap consisting of a dam with moderate head would not give as adequate protection downstream as the Bearspaw Power Development plan with a proposed head of forty-four feet. The former would cost some $1,000,000. and would only form a reservoir some one-half mile in length and due to the low height of the dam telescoping of ice-pack within the intervening thirty miles of the river up to the Ghost may cause ice to be discharged over the ice-trap, together with a flood of water.

Again a well known principle of water-power leases is to provide for maximum development at any water-power site. In fact the terms of agreement between the Government of the Province of Alberta and the Calgary Power Ltd. provides that the next development undertaken by that Company on the Bow River will be at the Bearspaw site. This development could be so planned that an

ice-trap be first built and later incorporated into the permanent dam. However, as an ice-trap would give less protection to Calgary - Bowness area, the Commission must therefore, in view of all the circumstances, consider the final development of the Bearspaw site, because when operated as a power development, there will be other advantages the principal one being the regulation within narrower limits of the fluctuating flow occasioned by the operation of the Ghost plant. The Bearspaw site is situated about ten miles west of Calgary and some thirty miles east of Ghost plant. The head is forty-four feet and the proposed capacity is 25,000 h.p.

While the dam will create a reservoir some five and one-half miles long the water will not be used for storage purposes as the plant will operate on the water provided from the operation of the Ghost plant.

The advantages to be secured from the standpoint of winter flooding in the Calgary - Bowness area, are as follows,-

(a) the forty miles of ice forming conditions between Ghost plant and Calgary would be reduced to ten miles as a maximum;

(b) under ordinary winter conditions it is expected that this would be further extended by ice free conditions below Bearspaw for from two to five miles, leaving only from five to eight miles of ice forming conditions between Bearspaw and Calgary;

(c) should additional measures be required between Bearspaw and Calgary a simple and not costly ice-trap would take care of the situation as there would be comparatively little ice to contend with as everything upstream from Bearspaw will be taken care of;

(d) the production of power at Bearspaw, even under peak load conditions, will not result in such fluctuating conditions at Calgary as now exist from the Ghost plant, which have been accentuated by ice forming and jamming conditions over the forty mile stretch of river. This reduction to from five to eight miles will be beneficial;

(e) It fits in with the general plan of the proposed power development of the Bow River. The important Shepard site could only be developed with the development of Bearspaw as a prerequisite. By this it is not meant that the problem of the Shepard site is automatically solved by the Bearspaw dam, as other factors will yet have to be solved.

The Commission recommends that the construction of the Bearspaw Dam be built as offering the most important single solution to ice jamming and flooding in the Calgary - Bowness area.

(d) Dykes. In respect to dykes, the Commission is in accord with the report of the Permanent Flood Committee, January 16th and 17th (Exhibit 33 (in part) as follows,-

"The result of the dyking work and walls constructed during 1951 was in general considered very successful. An elevation of twelve and one-half feet above 3,000 c.f.s. open water level was selected by this Committee earlier in the year to be the top level to which all dykes were to be constructed. All dykes were not completed to this elevation during the year but the most important areas were protected to this height. High backwaters were experienced at new locations with water levels even with the top of the dykes. As points of high backwater cannot be determined in advance, the areas that had flooded in previous years received prior attention. Very minor flooding over dykes or seepage through them was experienced and the over-all result was satisfactory. Without dykes this year there would have been larger areas than ever before flooded from the surface.

"The Committee considered the question of widening and rip-rapping all dykes. During the ice forming conditions with high water there is little or no erosion on the sides of dykes. The length of peak flows during possible summer floods has always been of short duration. It was, therefore, considered that widening and riprapping would be unnecessary at this time unless erosion justifies this action at a later date. It is recommended, however, that all dykes immediately fronting and protecting dwellings be loamed and seeded which would increase the resistance of the dykes to erosion as well as improve the appearance. It is further recommended that all locations be checked again for elevation and that additional dykes be constructed if not already in place. The dyke on part of the Sunnyside Boulevard, was never raised to the level selected by the Committee because of the objection of the residents fronting on the river. The Committee recommends the raising of this dyke to the selected height.

"As already pointed out in the flood report of 1946 dykes were never considered of value in alleviating underground seepage. Practically all the trouble experienced in Calgary this year was due to this condition. Underground stratas adjacent to the river are comprised of river gravels and therefore with high water levels in the river seepage cannot be prevented. The existence of water bearing gravels is a well known condition in Calgary

particularly in the areas adjacent to the river. The combatting of the seepage problem would require complete underground studies and has no apparent solution at the present time.".

Further in respect to this matter, it is anticipated that the growing demand for power from the Bow River system will result in higher and higher minimum flows during the winter months, also as there is always a grave danger from spring and summer floods due to unusual climatic conditions, consideration should be given to increasing the height of dykes at vulnerable points where high backwaters may be expected to occur (See Figure 10 showing dykes constructed). Dyking or cribbing at points in the Bowness and Bowcrest area would also be beneficial.

(e) River Improvements. After the construction of the Bearspaw Dam and the winter regime of the river has been established, a study should be made towards what measures should be taken to streamline the river in the Calgary-Bowness area, remove obstructions, etc. with the object of preventing ice jamming and the elimination of high backwaters, which cause flooding and damage from seepage in built on areas.

(f) Seepage. Large portions of Calgary and Bowness are built on flood plains created by the Bow and Elbow Rivers. The sub-soil is therefore composed of water borne material consisting of boulders, gravel and sand all of which are pervious to water. This flood plain area is also situated in a valley surrounded by high hills.

The above conditions are ideal for the creation of seepage, both from the high land into the previous flood plain area and from the river into the same area. The seepage from the river is always present and more positive in character and the height to which it rises depends on the surface level of the river or height of backwater. Also the effect of seepage becomes more apparent near the river banks. Seepage from the high land increases with chinooks and rainfall.

The above conditions create a serious and difficult problem to solve, except at high cost. The resultant damage to property holders is high. Seepage is not especially a winter problem, as the same results are obtained in the spring or summer, depending on the height of stage of the river. It is true, that, in general the flow of the Bow River is lower in the winter than in the summer, but the high backwaters, resulting from ice jamming raises the level of the river at many locations. The seepage problem in this area has become more serious recently through the encroachment of buildings towards the river banks. This is especially true in the area west of Calgary.

Plate 4 is an aerial photograph of this area taken in 1926 while Plate 5 is a similar one taken in 1949. A comparison of Plate 4 with Plate 5 shows that in 1926 there were less than a dozen buildings situated near the banks of the Bow River in the Bowness area, while in 1949 almost the whole area has been built up. Some of these buildings have been built on areas where incipient ice jamming or spring or summer floods occur which can cause serious damage. This is especially true of Bow Crescent and a portion of Bowness.

It will be noted that there is a sharp bend of the river at Bowness just beyond Shouldice Bridge, and the channel of the river is very narrow and is being further restricted by land slides caused by natural conditions. There is a large gravel bar just below this point and as stated before (See Figure 11) this is a point where ice jamming occurs with high backwater which continue up towards Bowness bridge.

The whole question of allowing buildings to be built on

critical flood areas is alarming, not only on the Bow River but elsewhere in Canada and the United States. In Canada the Winnipeg flood and Fraser River disaster are cases illustrating this point. As an illustration of the seriousness of the flood control problem in the united states, flooding on the Missouri caused over two hundred million dollars damage. Along a thousand mile stretch two million acres of farmland were under water and 130,000 people were homeless. After a tour of the area President Truman accused Missouri Valley governors of not supporting adequate control measures. He planned to recommend that Congress streamline the multi-headed administration of the Pick-Sloan Plan for Missouri Valley flood control and irrigation. This plan calls for the construction of 105 dams and reservoirs which would have the effect of preventing floods. The cost of this plan is estimated at <u>six billion dollars.</u>

Conditions of heavy snowfall in the Rocky Mountains, followed by warm winds and heavy rains could cause serious spring or summer floods in the Calgary - Bowness area.

All the rivers that rise on the Eastern slope of the Rocky Mountains are becoming of greater and greater importance to Alberta for irrigation and power purposes, especially since the resources of Alberta are so great and varied that industrialization is taking place at a very rapid rate. Less than twenty years ago the Province was largely dependent on agriculture along.

(g) <u>Bow River Control Board.</u> As the Bow River is of great importance to Alberta, both from the standpoint of power and irrigation, and as there is a critical flood problem in the Calgary - Bowness area which may

become serious as time goes on, the Commission recommends that a Bow River Control Board be set up to deal with the whole matter of the control of this river from the standpoint of floods, seepage and remedial measures. The Board would be a fact finding engineering body, separate from any administrative Government department. As it could not usurp the functions of Government, it would be advisory in character in respect to Government administration.

The purpose of the Board would be to study and secure the necessary information upon which to advise, and within the above limits, to carry out its investigations.

At the present time engineering plans and data in respect to the Bow River itself are of too meagre a character upon which to base any definite conclusions. Again improvements and new developments will all have an effect on present conditions. The question of seepage is an important one, but nothing can be done until detailed investigations have been made in respect to the nature of the sub-soil, old river channels, drainage from the surrounding hills, effect of flood plain of the Elbow river, a study of incipient ice jams in the river, the effect of ice traps now existing on the river pollution etc.

Many improvements can be made in the river bed itself which will tend to prevent flooding. A study should be made of these. Studies should also be made in respect to dykes. These would include locations, riprapping at certain places and the height of dykes to be established under changed conditions from time to time.

The Board could request specific studies to be made of ice engineering at the University of Alberta or National Research Council.

The monies required to finance the required work under the

direction of the Board, to be provided by the Government of the Province of Alberta, Calgary Power Ltd and the City of Calgary, Bowness et al.

It is suggested that the above parties have engineering representation on the Board and that the Director of Water Resources, Province of Alberta, be Chairman; a representative of the Water Resources of the Dominion, also to be a member of the Board.

(h) The Commission further recommends that appropriate legislation be passed,-

(i) to prevent settlement or building on areas which, in the opinion of authority are subject to serious danger from flooding;

(ii) to cause to have buildings removed from critical flood areas where reasonable protection cannot be provided.

It is admitted that in respect to the latter the problem may be difficult on account of vested interest, but nevertheless it is most desirable that this be done.

(i) The Bowness steel bridge is constructed across the Bow River just below the Bowness Park lagoon. The height of the deck of the bridge is too low to give sufficient clearance in case of an ice jam which may build up from a point near Shouldice Bridge.

In 1951 the north end of the south truss of the bridge was shifted some ten inches on its pier from a pack lodged about one-quarter of a mile from Shouldice Bridge. This is the second occasion that this bridge has been affected by ice jamming and the Commission recommends that the approaches to the bridge be regraded and the bridge raised to a suitable higher level.

VIII SUMMARY AND RECOMMENDATIONS.

The Bow River in its natural state was capable of producing only some 2,500 h.p. in the winter months. The climatic conditions are such that the high summer flow of the river is some three hundred times the minimum winter flow. Storage reservoirs constructed at the headwaters have been the means of converting this river into the most important power development in the Province.

The installed capacity of eight plants now amounts to 209,050 h.p., and the ultimate capacity is some 575,000 h.p. The demand for power from this source in Alberta is increasing rapidly, being some 200 million k.w. hrs. in 1941 and over 700 million k.w. hrs. in 1951. The power developed is being distributed to more than half the settled area of the Province, including towns, villages and farms.

From the above it is evident that the principle of conservation of flood run-off water has enured to the benefit of the Province as a whole.

The increase in the winter flow has naturally affected the winter regimen of the river. The average winter flow in its natural state was as low as 300 c.f.s. This has been increased, or is capable of being increased, to some 3,200 c.f.s.

Winter floods occurred in the Calgary - Bowness area from ice jamming before storage reservoirs were constructed,but records show that they have occurred more frequently under higher winter flow.

It is true that in recent years the average winter temperatures have been lower than formerly, but whether this would account for the increased frequency of winter flooding or not, it is most difficult to say. It is

certain that the storage reservoirs have a marked effect in reducing the amount of ice formed as they effectively trap all ice formed above their locations. The Ghost plant, for example, not only traps all ice coming to the reservoir, but also releases water at a temperature a little above freezing so that there is a considerable distance of ice free water varying with the temperature before freezing takes place. The Ghost plant is operated as a peak load plant and therefore the water discharged fluctuates in wide limits from 150 c.f.s. to 3,500 c.f.s.

During the past few years the Permanent Flood Committee were of the opinion that in this forty miles of river ice gouging and telescoping which occurred during daily fluctuating flows contributed to ice jamming and that a fairly high uniform flow would be advisable.

Uniform flow was made operative December 6th to 9th at a rate of 2,800 c.f.s. On December 9th, owing to mild weather,uniform flow was discontinued temporarily. On December 13th it was re-established at a rate of 3,000 c.f.s. until December 22nd. On December 22nd it was reduced to 2,200 c.f.s. until January 25th, 1952. The general observation of the Committee was that uniform flows did not result in improved conditions in the Calgary-Bowness area. The backwaters resulting from the uniform flows of 1951-52 were as high as the backwater stages observed during the fluctuating flows of previous years. The results secured from this experiment were therefore negative. It appears that regulation from the Ghost plant is not a solution to the winter flood problem on account of its distance from Calgary and the many points in between where incipient ice jams may occur. In conclusion the Committee states,-

"River studies to the present time have not established that uniform flows are more advantageous than fluctuating flows, but it is the concensus of the Committee that high minumum flows would be preferable to the low minimum flows of the past years.".

RECOMMENDATIONS

Ice jamming and winter flooding has occurred on the Bow River in the Calgary - Bowness area before the winter flow had been increased by the construction of storage reservoirs. It now occurs more frequently under fluctuating flow and the recent experiment of uniform flow gave no solution. The evidence presented to the Commission was practically unanimous to the effect that the Bearspaw Power Development would go a long way towards solving the problem of winter flooding in the Calgary - Bowness area.

1. The Commission is in agreement with this proposal and recommends the construction of the Bearspaw development as soon as possible as offering the most important single solution to ice jamming and flooding in the Calgary - Bowness area.

2. As the problem of flooding and seepage is a continuous one even after Bearspaw is developed, the Commission recommends that a Bow River Control Board be set up to deal with the whole question of the control of this river from the standpoint of floods, seepage and remedial measures.

3. The Commission further recommends that appropriate legislation be passed,-

(a) to prevent settlement or building on areas which in the opinion of authority are subject to serious danger from flooding;

(b) to cause to have buildings removed from critical flood areas, where reasonable protection cannot be provided.

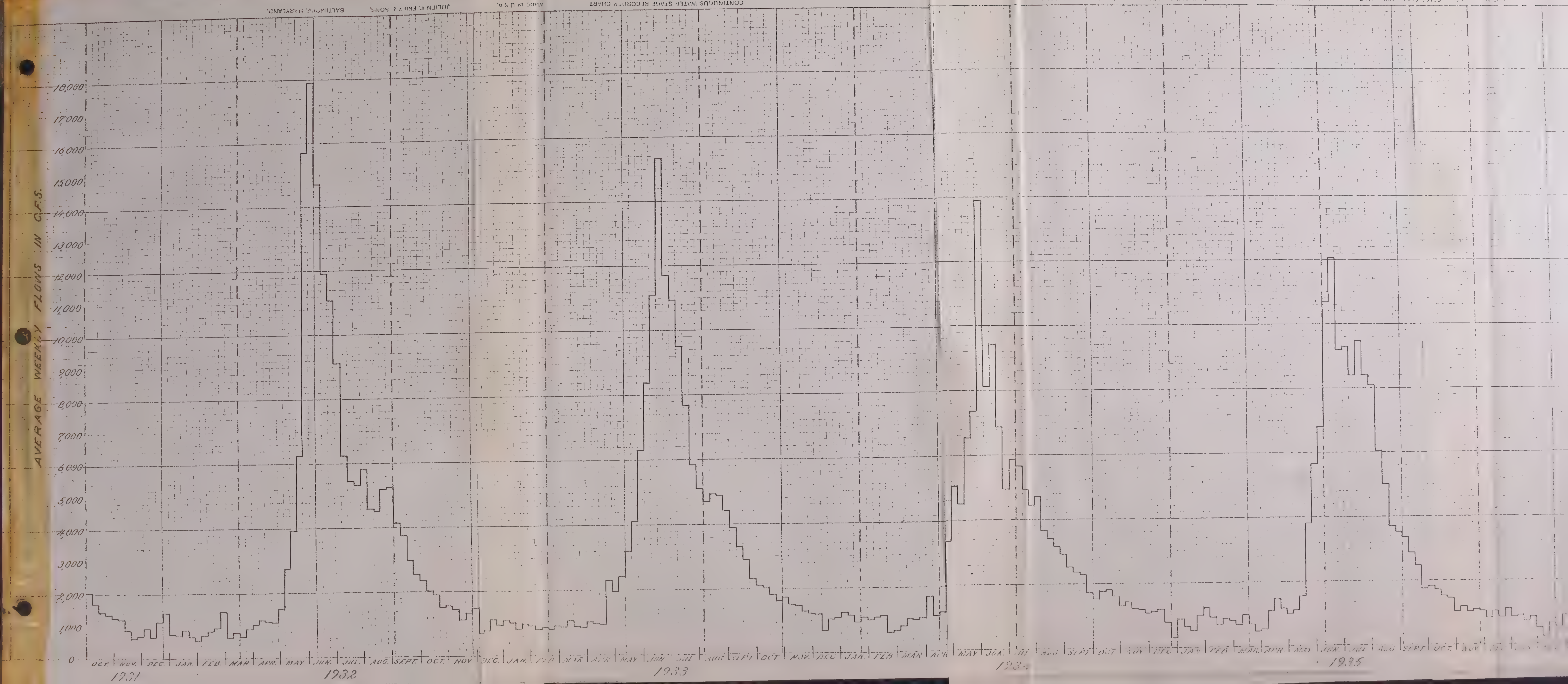
4. The Commission recommends that the Bowness steel bridge be raised to a suitable height to prevent its loss or damage by ice jamming.

5. The Commission recommends extensions of dykes in Calgary and cribbing or dyking in places in the Bowness area. Also that consideration be given to increasing the height of the present dykes to take care of possible spring or summer floods.

6. The Commission is unable to make any specific recommendation in respect to the solution of the seepage problem on account of insufficient information. This matter requires further investigation as under Recommendation 2.

7. Certain abnormal climatic conditions can happen at the headwaters of the Bow River system that would cause serious spring or summer flooding in the Calgary - Bowness area. These conditions are,- much above normal snowfall in the mountains during the winter followed by warm westerly winds in the late spring or summer accompanied by excessive rainfall that causes the snow to melt rapidly before the ground has a chance to become unfrozen and the water soak in. Normally, some snow melts each day, but at night the temperatures drop below freezing, in the mountains, and the thaw slows. The only recourse when such a condition is expected, is to take advantage of the storages now constructed and see that they are drawn down to such a level as to take care of such emergency.

This would also be a function of the recommended Bow River Control Board.


AVERAGE WEEKLY FLOWS IN C.F.S.
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV.
1931
1932
1933
1934
1935

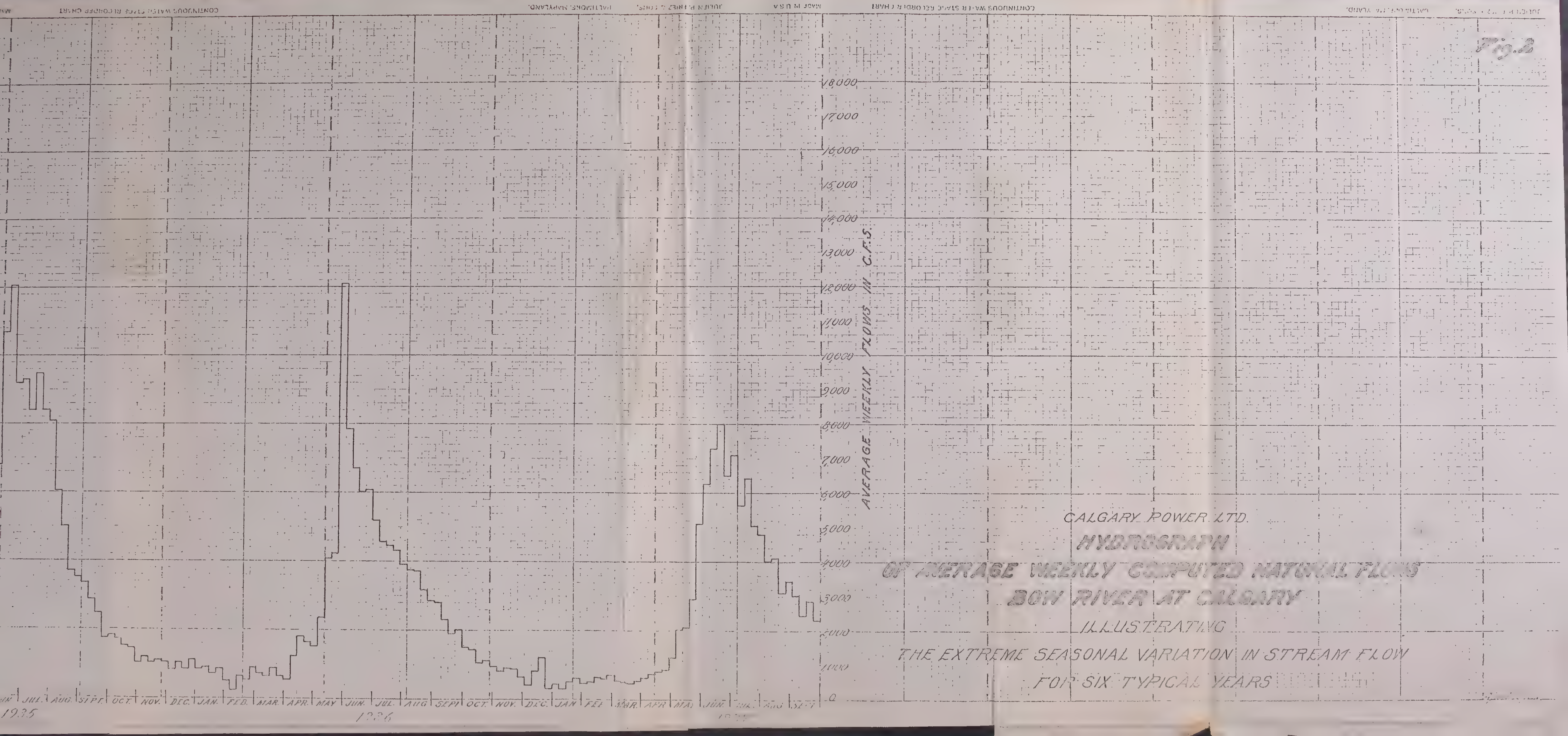


Fig. 2
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
AVERAGE WEEKLY FLOWS IN C.F.S.
JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT.
1935
1936
CALGARY POWER LTD.
HYDROGRAPH
OF AVERAGE WEEKLY COMPUTED NATURAL FLOWS
BOW RIVER AT CALGARY
ILLUSTRATING
THE EXTREME SEASONAL VARIATION IN STREAM FLOW
FOR SIX TYPICAL YEARS

Figure 3

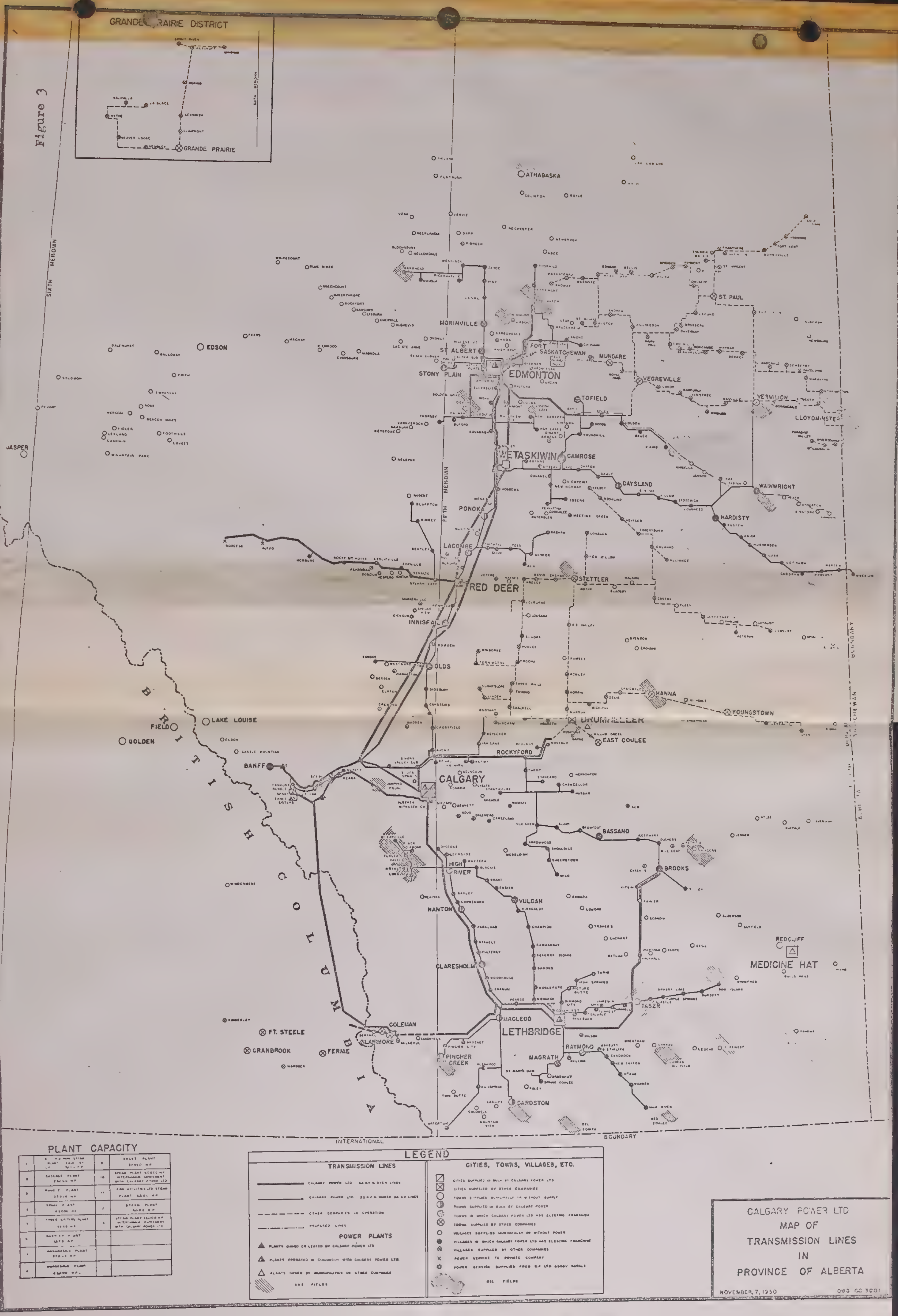

GRANDE PRAIRIE DISTRICT
GRANDE PRAIRIE
SIXTH MERIDIAN
FIFTH MERIDIAN
ATHABASKA
EDSON
JASPER
MORINVILLE
ST ALBERT
FORT SASKATCHEWAN
MUNDARE
STONY PLAIN
EDMONTON
VEGREVILLE
ST. PAUL
TOFIELD
VERMILION
LLOYDMINSTER
WETASKIWIN
CAMROSE
DAYSLAND
WAINWRIGHT
PONOKA
HARDISTY
LACOMBE
RED DEER
STETTLER
INNISFAIL
OLDS
HANNA
YOUNGSTOWN
DRUMHELLER
EAST COULEE
LAKE LOUISE
FIELD
GOLDEN
ROCKYFORD
BANFF
CALGARY
BASSANO
BRITISH COLUMBIA
HIGH RIVER
BROOKS
VULCAN
NANTON
CLARESHOLM
REDCLIFF
MEDICINE HAT
COLEMAN
BLAIRMORE
FT. STEELE
CRANBROOK
FERNIE
PINCHER CREEK
MACLEOD
LETHBRIDGE
TABER
RAYMOND
MAGRATH
CARDSTON
INTERNATIONAL
BOUNDARY
PLANT CAPACITY
LEGEND
TRANSMISSION LINES
CITIES, TOWNS, VILLAGES, ETC.
POWER PLANTS
CALGARY POWER LTD
MAP OF
TRANSMISSION LINES
IN
PROVINCE OF ALBERTA
NOVEMBER 7, 1950

Fig. 4

FARM ELECTRIFICATION

IN THE PROVINCE OF ALBERTA

(AS AT MARCH 1st, 1952)

RURAL ELECTRIFICATION *in the* PROVINCE OF ALBERTA

(AS AT MARCH 1st, 1952)

CALGARY POWER LTD. — Through Its Subsidiary FARM ELECTRIC SERVICES LTD.

1 Olds
2 Taber
3 Bremner
4 Red Deer
5 Sturgeon
6 Lethbridge
7 Glenwood—Hillspring
8 Ponoka
9 Acme
10 Springbank
11 Strathcona
12 Fairview
13 [illegible]kfalds
14 Coaldale
15 Gem
16 Lacombe
17 Rosemary
18 [illegible]kville
19 Bow North
20 Irricana
21 Angus Ridge
22 Frank Lake
23 Markerville
24 Winterburn
25 Cranford
26 Gladys
27 Ridgewood
28 Carstairs
29 West Wetaskiwin
30 Wang
31 Big Bend
32 Vauxhall
33 Little Red Deer
34 Rosebud
35 West Didsbury
36 Raymond
37 Wainwright
38 One Tree
39 Wabash
40 Ray
41 Cassils
42 Penhold
43 Leduc West
44 West Liberty
45 Park Lake
46 West Airdrie
47 Lyalta
48 Beiseker
49 Longview
50 Parkland
51 Okotoks-DeWinton
52 Blindman Valley
53 Clearwater
54 Cremona
55 Mountain View
56 Bowden No. 1 & No. 2
57 Foothills
58 Fredricksheim
59 Spruce Grove
60 Evergreen
61 Battle River
62 Turin-Iron Springs
63 Bow Slope
64 Red Deer West
65 Neutral
66 Vulcan
67 Harmony
68 Connemara
69 Waterglen
70 Namaka
71 Hampton
72 Balzac
73 Stony Plain
74 Fort
75 Armena
76 Chief Mountain
77 Auburndale
78 Gilbey
79 Usona
80 Barons
81 Sylvan
82 Cayley
83 Brant
84 Bowden No. 3
85 Ervic
86 Crossfield
87 Gibbons-Bon Accord
88 Leslieville
89 Warner
90 Stavely
91 Amisk
92 Rockyford
93 Pulteney
94 Bruderheim
95 Clive
96 Legal
97 Kingman
98 Tilley
99 V.N.M.
100 Millarville
101 Boundary
102 Rolling Hills
103 Milo
104 Border
105 Fire Guard
106 United
107 Mossleigh
108 St. Mary's
109 Central Community
110 Chipman Creek
111 Hollandale
112 Daysland
113 Tofield
114 Ardrossan
115 Mearns
116 North Killam
117 South Killam
118 Strome
119 Chauvin
120 Duffield
121 Hudson
122 Sedgewick
123 Gratton
124 Strawberry
125 North Edgerton
126 South Edgerton
127 Hayter
128 Provost
129 Ryley
130 Holden
131 Lockhart
132 Ortton
133 Lynaria
134 White Cloud
135 Grainger
136 Burdett
137 Rocky Mtn. House
138 Roseberry
139 DelBonita
140 Black Diamond

CANADIAN UTILITIES LIMITED

1A Spirit River
2A Wanham
3A Valhalla Center
4A Pioneer
5A Scenic Heights
6A Beaver Lodge South
7A Grande Prairie Individuals
8A Grande Prairie East
9A
10A
11A Grand Center
12A Ardmore
13A Bonnyville
14A [illegible]
15A Mallaig
16A St Vincent
17A St Paul
18A [illegible]
19A Stry
20A Wahstao
21A Waskatenau
22A [illegible]wale
23A Willingdon
24A Mundare-Hilliard
25A Ross Creek
26A Hairy Hill
27A Warwick
28A Brodie
29A Inland
30A Beaverhill Lake
31A Martins
32A Brush Hill
33A Lavoy
34A Ranfurly
35A Elk Point (North)
36A Elk Point (South)
37A Beauvallon
38A Myrnam
39A Derwent
40A Greenlawn Ext.
41A Greenlawn
42A Lea Park
43A Campbell Lake
44A Hazeldine
45A Bellcamp
46A Durness
47A Islay
48A Borradaile
49A Kitscoty
50A Devonia
51A Clasmore
52A Ottawa
53A Minburn
54A Auburndale
55A Paradise Valley
56A Merton
57A
58A
59A Nevis
60A Kelsey
61A Kelsey Ext.
62A Melrose
63A Sterling
64A Forestburg
65A Forestburg Ext.
65AA Forestburg Ext.
66A Up-to-Date
67A Spruce Coulee
68A Science Mound
69A Red Willow
70A Stettler
71A Sabine
72A Fenn
73A Zenith
74A Endiang North
75A Craigmyle
76A Scapa
77A Hanna
78A Veteran
79A Delburne West
80A Delburne
81A Lousana
82A Elnora
83A Huxley West
84A Huxley Ext.
85A Torrington
86A East Trochu
87A Rowley
88A Rowley Ext. (1952)
89A East Rowley Ext.
90A West Rowley Ext.
91A Ghost Pine
92A Twining
93A Sunnyslope
94A Swalwell
95A Carbon
96A Munson
97A Michichi
98A C.L.V.
99A Over the Hill
100A Wayne
101A Wintering Hills
102A Castor
103A Alliance

NORTHLAND UTILITIES LIMITED

1B Manning
2B Burnt River
3B [illegible]
4B White Swan
5B McLennan-Girouxville
6B Wildwood
7B High Prairie
8B Jean Cote
9B Kirndale
10B Stewart
11B Rochfort Bridge
12B Saddle Valley

Figure 4

(See Story of Rural Electrification on Back Page)

The STORY of FARM ELECTRIFICATION

ON the opposite side of this page there is a map illustrating the progress which has been made in farm electrification over the past few years. This progress has been made possible by the excellent co-operation which has prevailed between the Farmers, the Government of Alberta and the Power Companies.

There are now 256 Rural Electrification Areas in Alberta either completed, under construction or proposed. Most of the credit for the progress which has been made should go to the farmers themselves, for their initiative, enthusiasm and co-operative effort.

For Alberta the best way of carrying out farm electrification is by the Rural Electrification Co-operative Association method. Under this plan the farmers who are concerned make the decisions themselves. Also the farmers in co-operation with each other and in co-operation with those who carry out the actual construction work can, and do, assist materially in keeping construction costs to a minimum.

Farm Electrification represents one of the largest and most effective jobs of co-operative effort ever carried out in Alberta. This is co-operation at its best. Considering the fact that only a handful of farmers had farm electrification in 1943, the advancement which has been made in less than ten years is really outstanding — something of which all those who had a part in this work—the Farmers, the Provincial Government and the Power Companies, can be justly proud.

The farmers are proud of their efforts and have a great feeling of accomplishment when a project is completed and the lights are turned on. They know that the people of the Province will have to pay for Rural Electrification in the long-run, either directly or indirectly. Those who through their own initiative have achieved this goal are very jealous of their position and would not stand for an increase of rates to subsidize projects which are too costly by virtue of the fact that the service was being extended to too sparsely settled areas.

In sparsely-settled, low-production areas farms are scattered. This increases the amount of line required per farm and consequently the cost of providing farm electrification. In some areas the cost will run as high as four times and more the cost of providing farm electrification in the more productive areas. Irrigation is proposed for some of the areas in the south-east and when irrigation is provided, farm electrification will then be economically feasible.

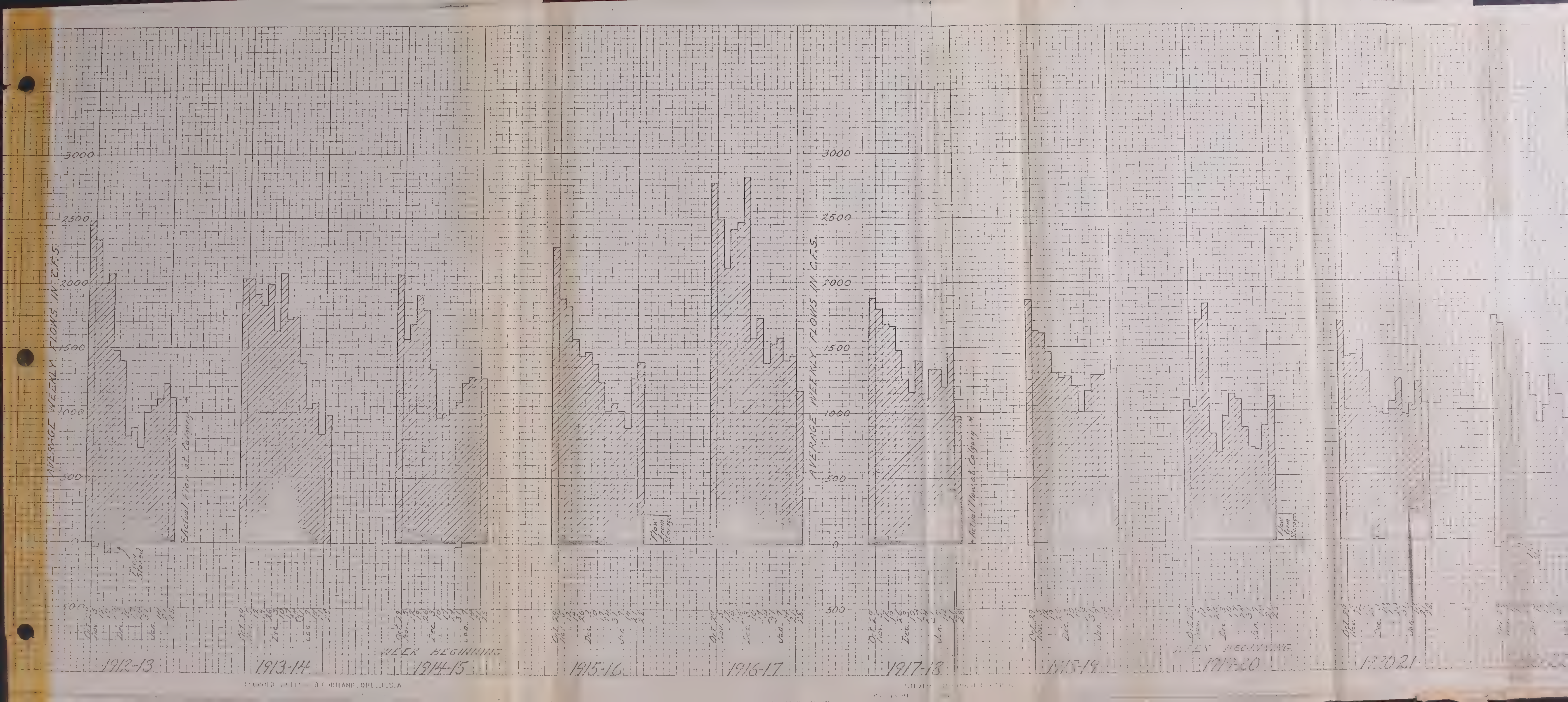
Electric service to farmers in Alberta is supplied by the power companies at cost. The farmer does not pay any of the first cost of the transmission line from whence the service to his area originates, but because he does pay for the actual rural lines, he enjoys a low energy rate for the power he uses.

Now, what of the future? First, Rural Electrification to new areas is going ahead on schedule. As time goes on more transmission lines will be built by the power companies in new locations and many of these are now in the planning stage. This will advance farm electrification because it will bring central station service close to areas where service to them now, because of their remoteness from present transmission lines, would be very costly.

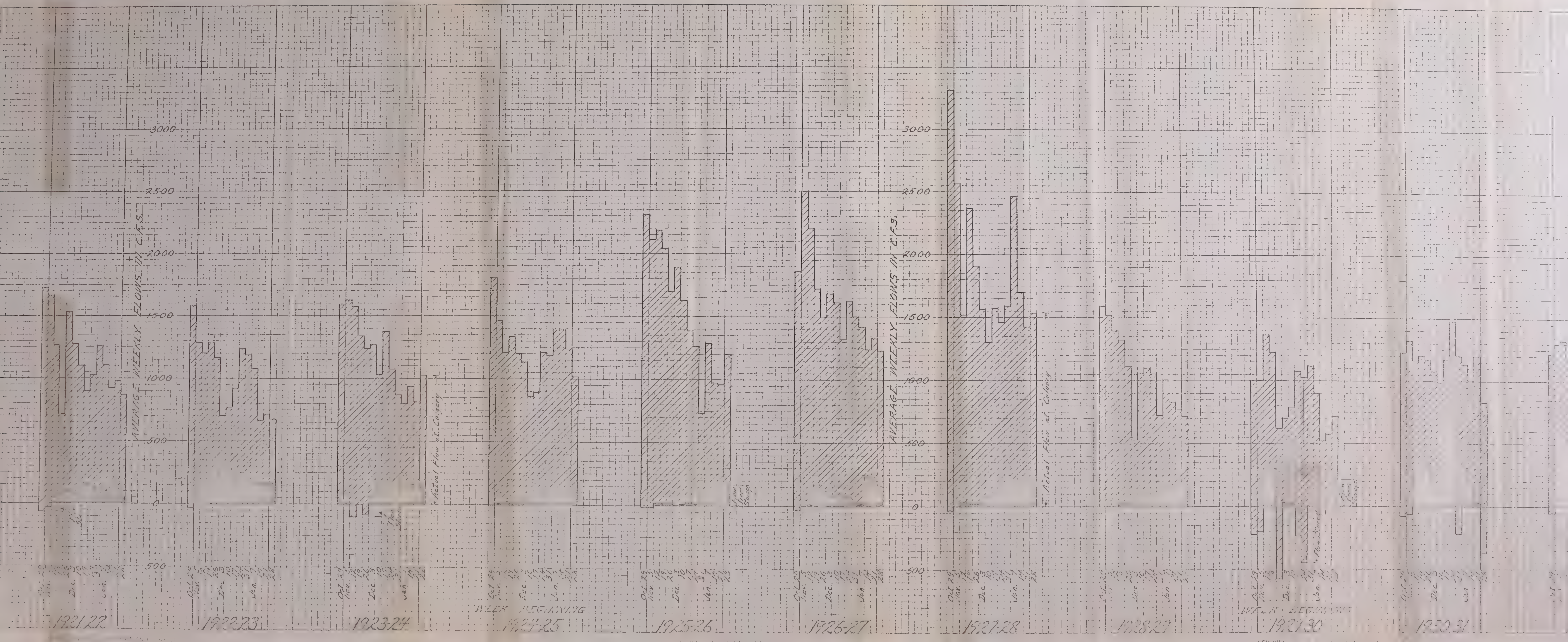
It is gratifying to note that recognition is given, in the farm sale market, to the investment made by farmers in getting farm electrification. Under the "Farms for Sale" heading in the newspapers it is noticeable that farms with electrification command a much higher price than those without farm electrification. The difference in price of farms is more than double the amount the farmers have invested in line construction costs and building wiring costs.

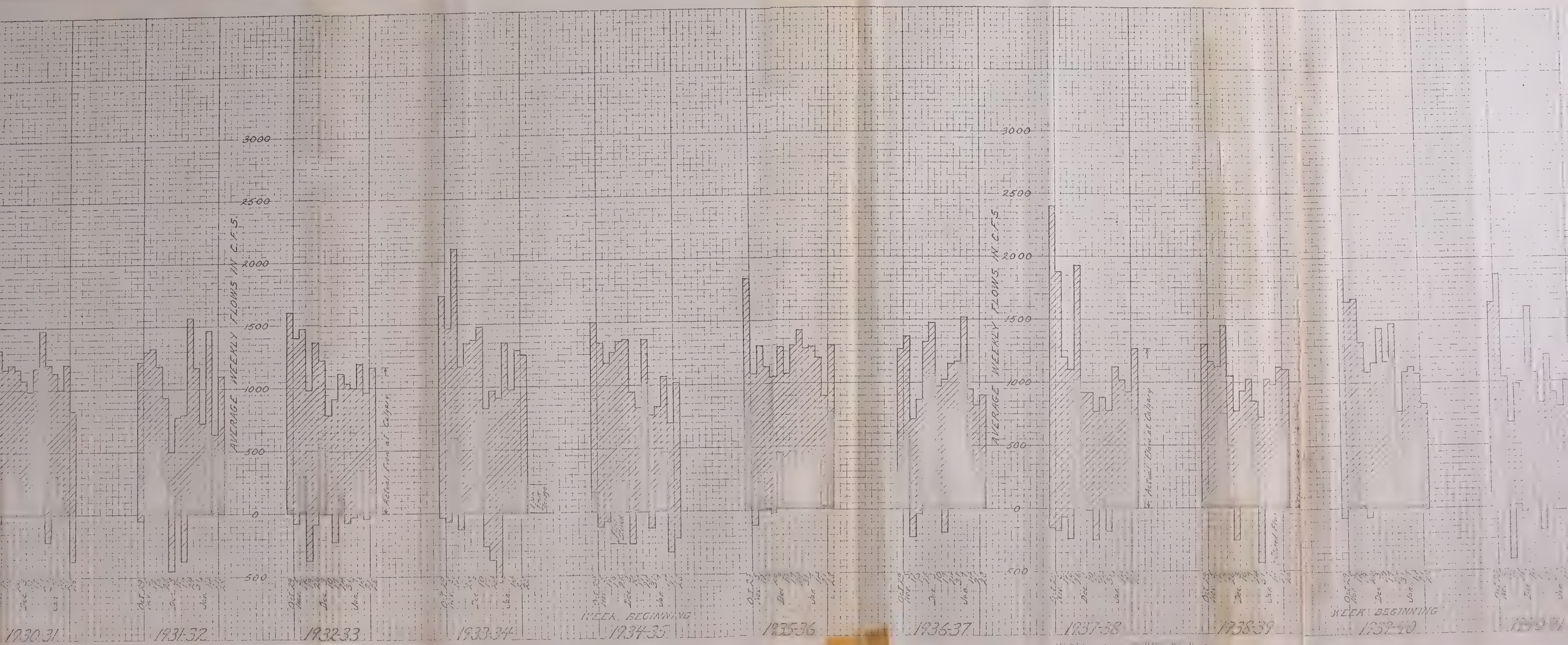
There is another partner in the Farm Electrification Co-operative Association plan whom we haven't mentioned. It is the farmer's wife. She has been one of the most effective forces in the successful progress which has been made. Not only has she been enthusiastic in supporting the forming of the associations, but in many cases she has provided the good meals for the construction crews at reasonable cost. Mrs. Farmer gets her reward when the power is turned on. She then has the opportunity of obtaining all the household appliances to take much of the drudgery out of household tasks.

Farmers, through Rural Electrification Co-operative Associations, are accomplishing a job in a successful way which could not be accomplished as well or at as reasonable cost by any other agency — and doing it themselves without calling on the taxpayers' money for help.

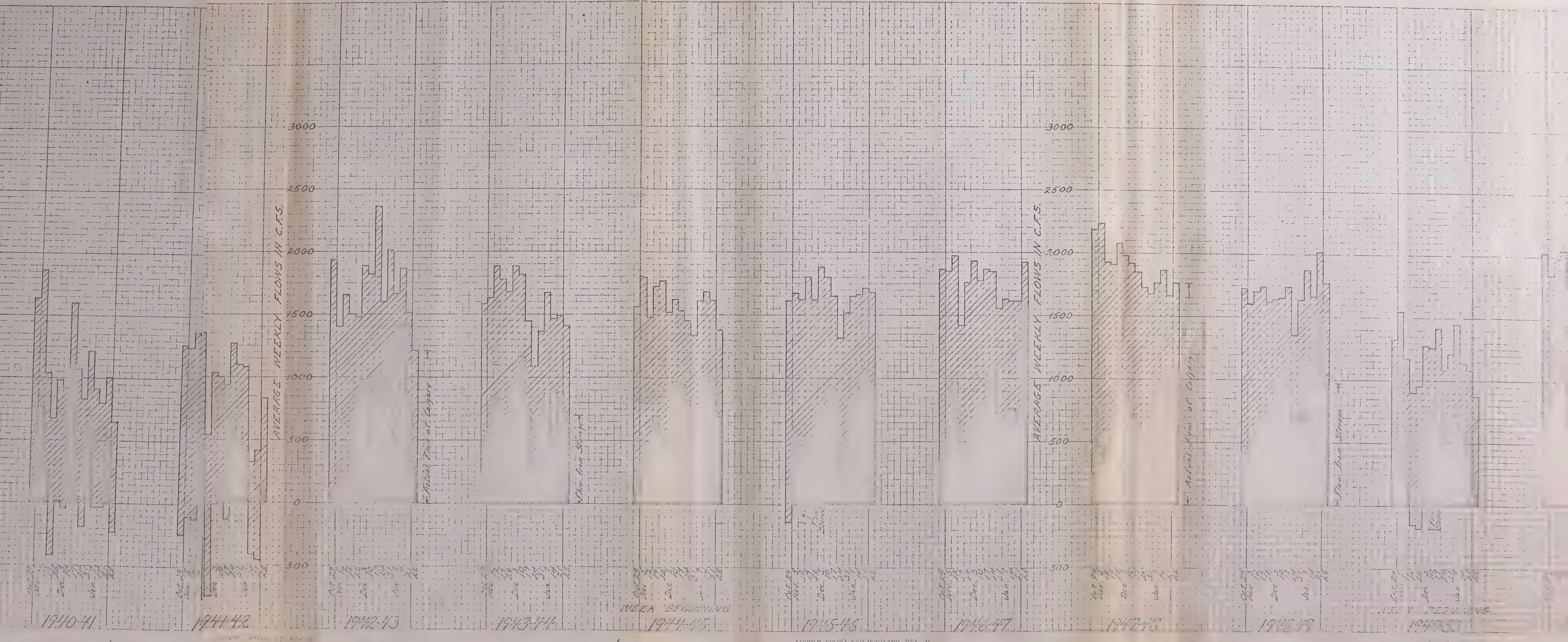


AVERAGE WEEKLY FLOWS IN C.F.S.
3000
2500
2000
1500
1000
500
0
500
Flow Stored
Actual Flow at Calgary
Flow from Storage
WEEK BEGINNING
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
1920-21


AVERAGE WEEKLY FLOWS IN C.F.S.
3000
2500
2000
1500
1000
500
0
500
Actual Flow at Calgary
WEEK BEGINNING
1921-22
1922-23
1923-24
1924-25
1925-26
1926-27
1927-28
1928-29
1929-30
1930-31



3000
2500
2000
1500
1000
500
0
500
AVERAGE WEEKLY FLOWS IN C.F.S.
* Actual flow at Calgary
WEEK BEGINNING
1930-31
1931-32
1932-33
1933-34
1934-35
1935-36
1936-37
1937-38
1938-39
1939-40



3000
2500
2000
1500
1000
500
0
500
AVERAGE WEEKLY FLOWS IN C.F.S.
Actual Flow at Calgary
Flow from Storage
WEEK BEGINNING
1940-41
1941-42
1942-43
1943-44
1944-45
1945-46
1946-47
1947-48
1948-49
1949-50
LEUPOLD VOLPEL & CO. PORTLAND, ORE.

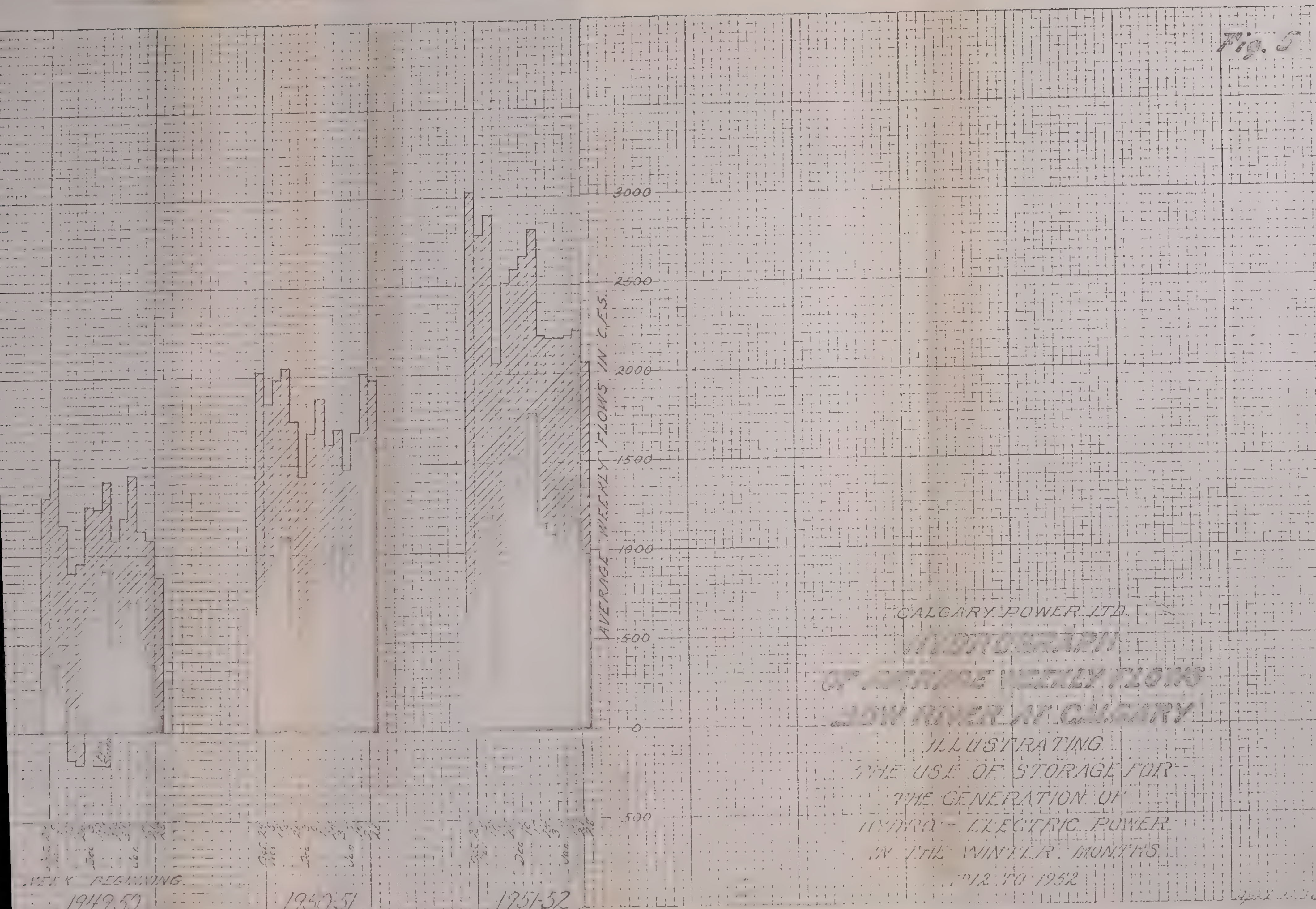
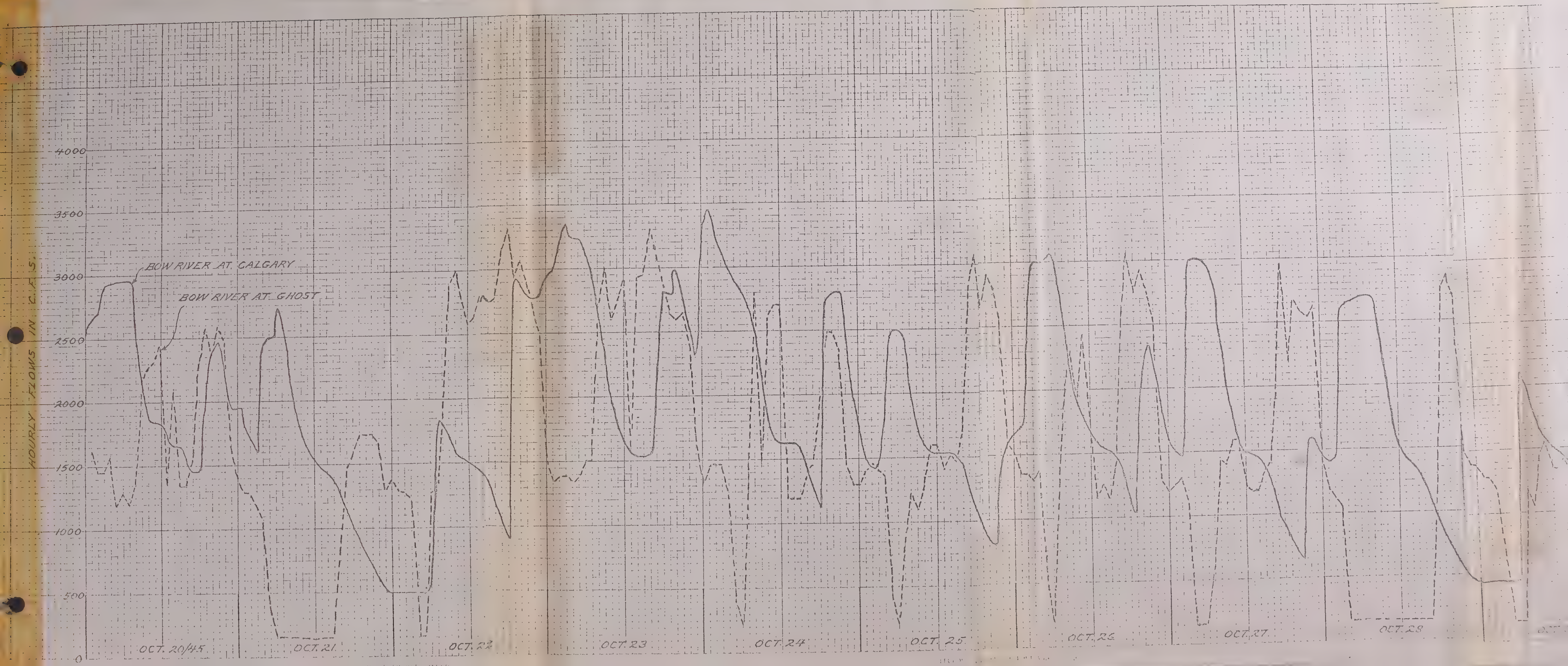
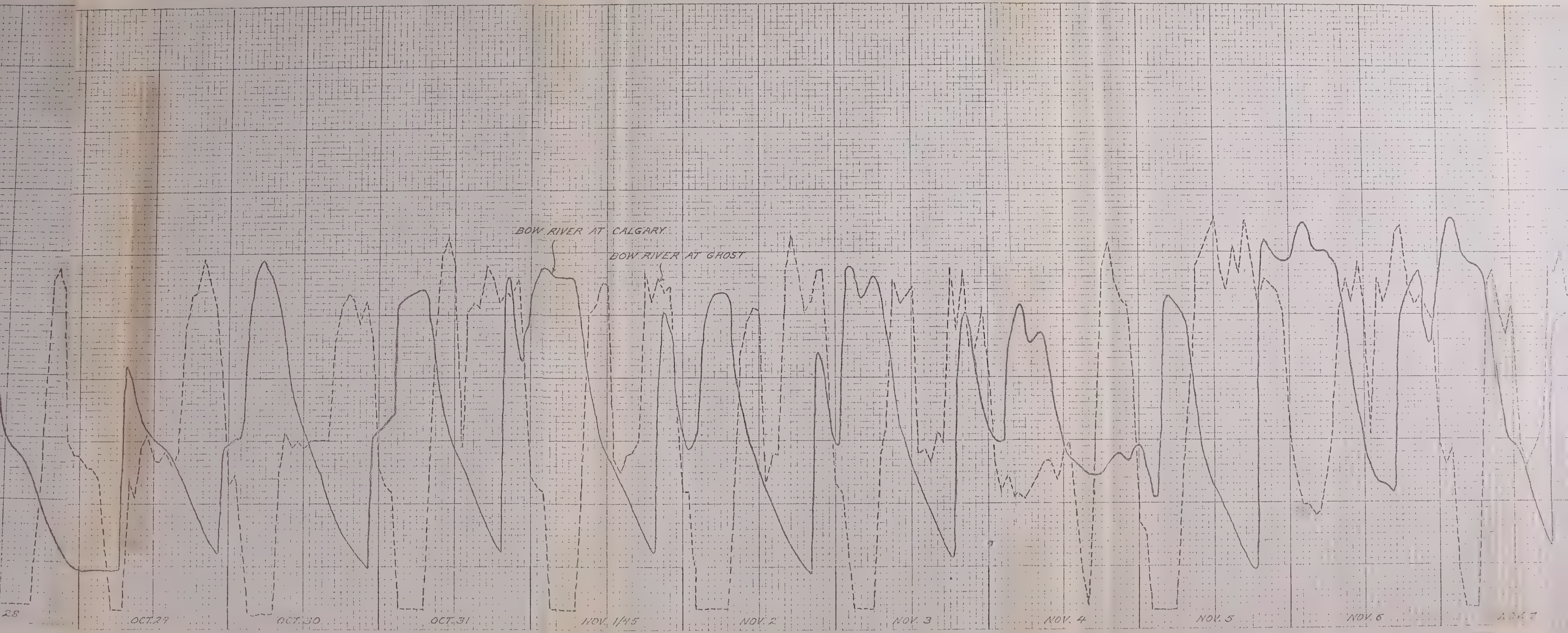


Fig. 5
AVERAGE WEEKLY FLOWS IN C.F.S.
3000
2500
2000
1500
1000
500
0
500
WEEK BEGINNING
1949-50
1950-51
1951-52
CALGARY POWER LTD.
ILLUSTRATING
THE USE OF STORAGE FOR
THE GENERATION OF
HYDRO - ELECTRIC POWER
IN THE WINTER MONTHS
1912 TO 1952



HOURLY FLOWS IN C.F.S.
4000
3500
3000
2500
2000
1500
1000
500
0
BOW RIVER AT CALGARY
BOW RIVER AT GHOST
OCT. 20/45
OCT. 21
OCT. 22
OCT. 23
OCT. 24
OCT. 25
OCT. 26
OCT. 27
OCT. 28


BOW RIVER AT CALGARY
BOW RIVER AT GHOST
28
OCT. 29
OCT. 30
OCT. 31
NOV. 1/45
NOV. 2
NOV. 3
NOV. 4
NOV. 5
NOV. 6

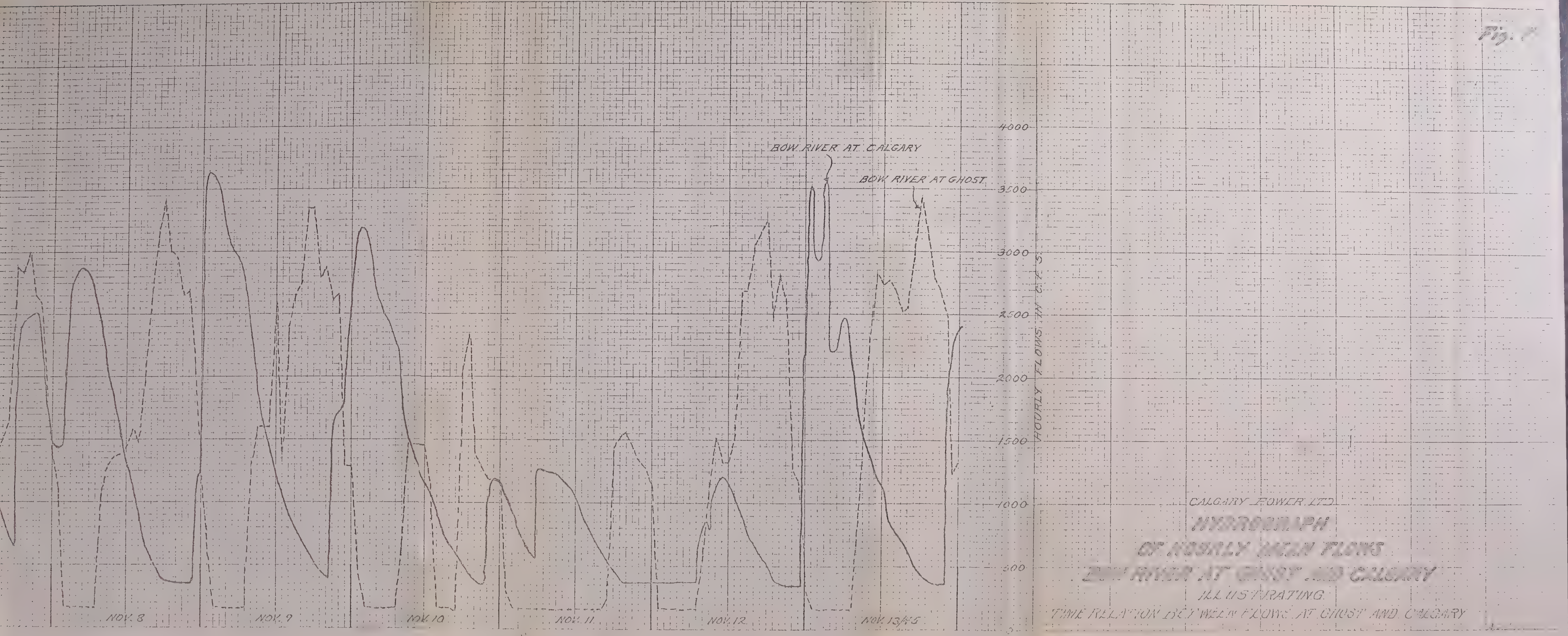
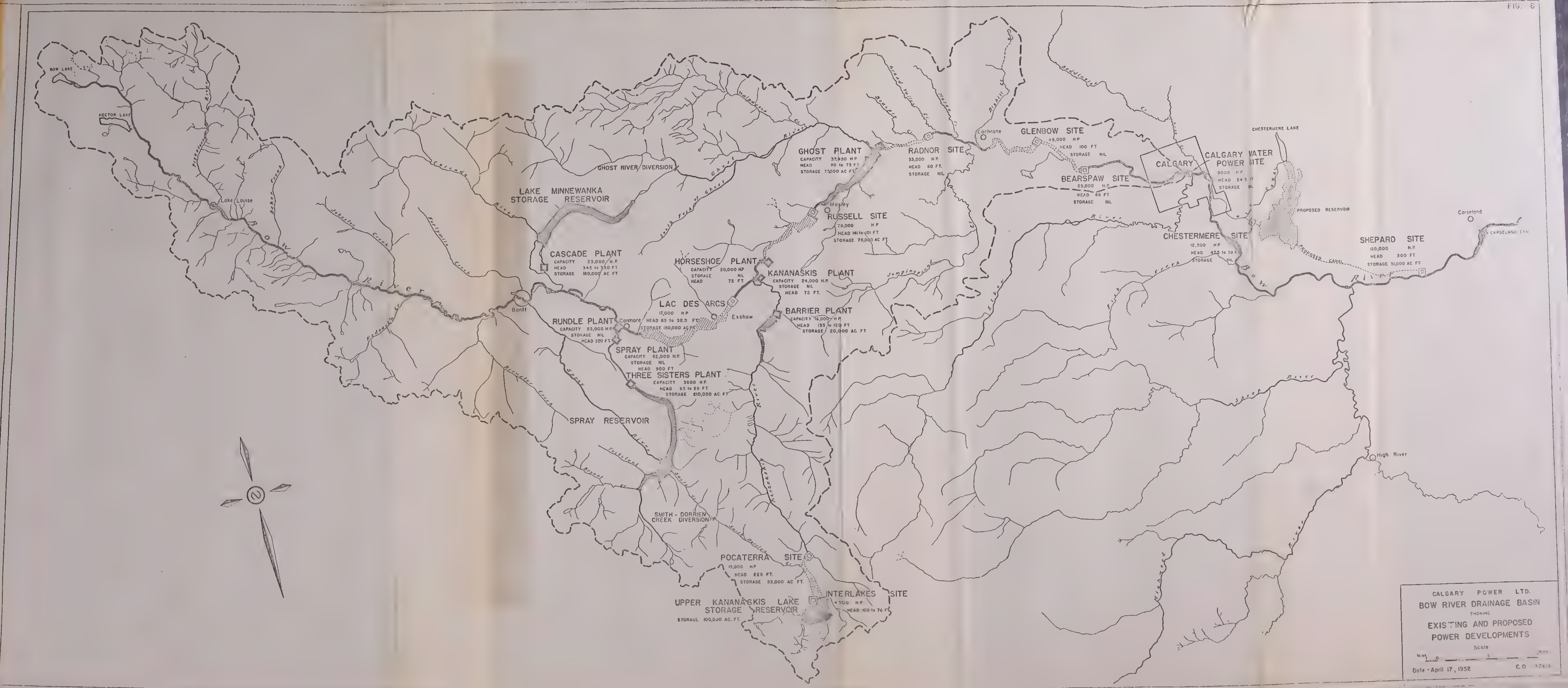
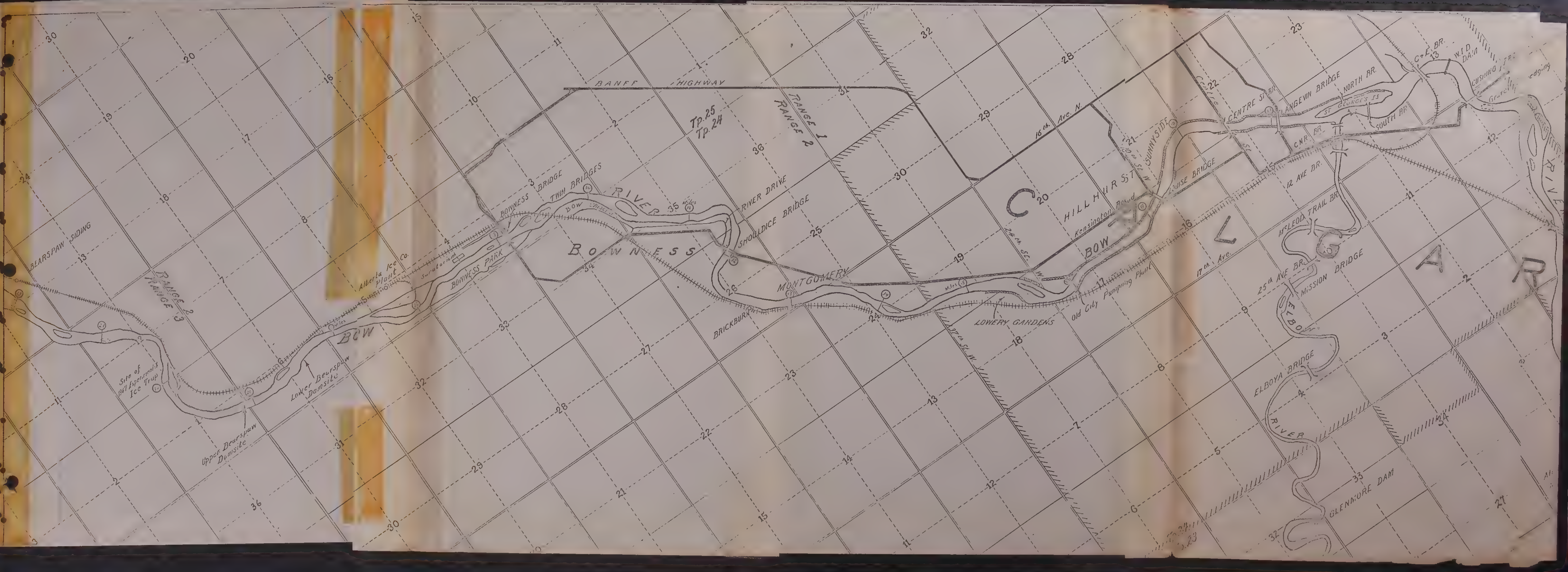
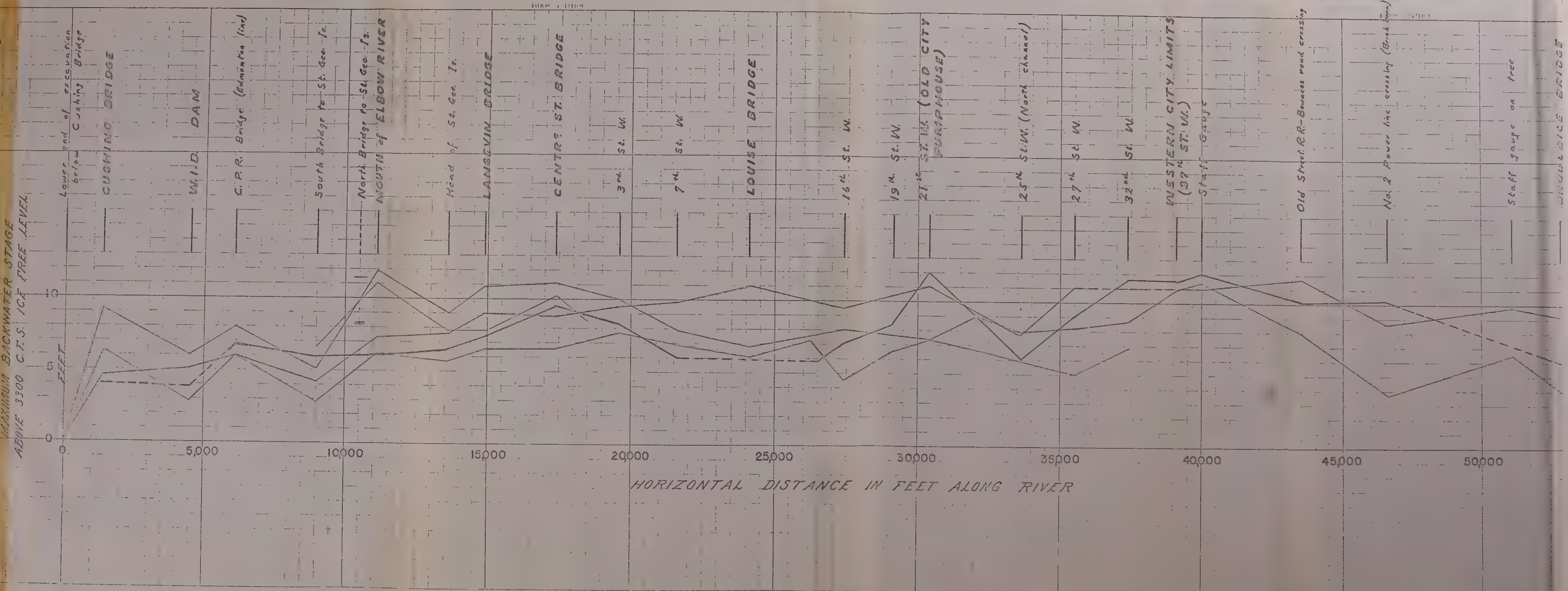


Fig. 1
BOW RIVER AT CALGARY
BOW RIVER AT GHOST
HOURLY FLOWS IN C.F.S.
4000
3500
3000
2500
2000
1500
1000
500
NOV. 8
NOV. 9
NOV. 10
NOV. 11
NOV. 12
NOV. 13/55
CALGARY POWER LTD
HYDROGRAPH
OF HOURLY MEAN FLOWS
BOW RIVER AT GHOST AND CALGARY
ILLUSTRATING
TIME RELATION BETWEEN FLOWS AT GHOST AND CALGARY

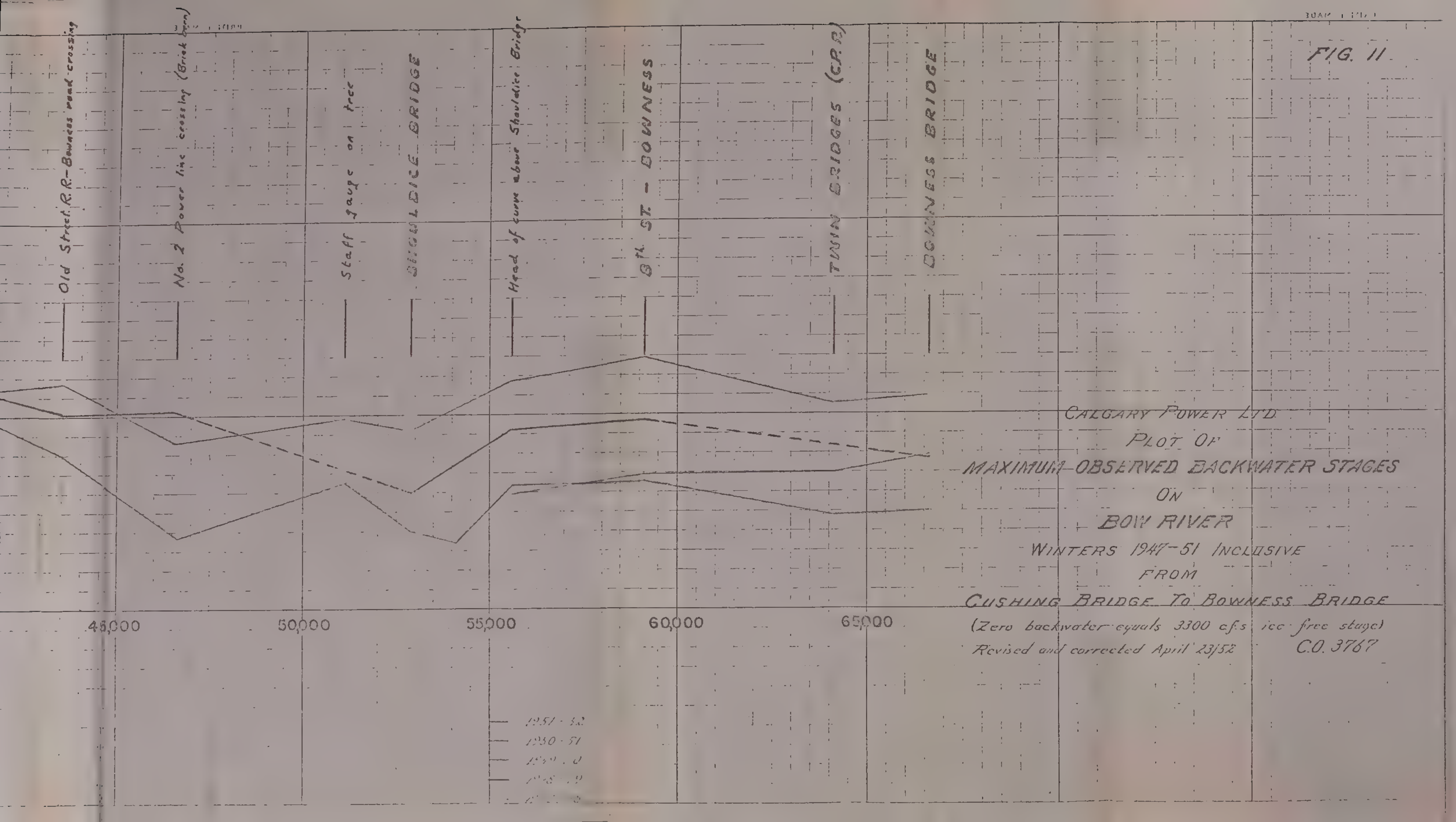
FIG. 8


BOW LAKE
HECTOR LAKE
Lake Louise
Bow River
GHOST RIVER DIVERSION
LAKE MINNEWANKA
STORAGE RESERVOIR
CASCADE PLANT
CAPACITY 23,000 H.P.
HEAD 345 to 330 FT.
STORAGE 180,000 AC FT.
Banff
RUNDLE PLANT
CAPACITY 23,000 H.P.
STORAGE NIL
HEAD 320 FT.
Canmore
SPRAY PLANT
CAPACITY 62,000 H.P.
STORAGE NIL
HEAD 900 FT.
THREE SISTERS PLANT
CAPACITY 3600 H.P.
HEAD 65 to 25 FT.
STORAGE 210,000 AC. FT.
SPRAY RESERVOIR
SMITH - DORRIEN
CREEK DIVERSION
POCATERRA SITE
19,000 HP
HEAD 226 FT.
STORAGE 53,000 AC. FT.
UPPER KANANASKIS LAKE
STORAGE RESERVOIR
STORAGE 100,000 AC. FT.
INTERLAKES SITE
4,500 H.P.
HEAD 100 to 76 FT.
LAC DES ARCS
17,000 H.P.
HEAD 65 to 32.5 FT.
STORAGE 130,000 AC. FT.
Exshaw
HORSESHOE PLANT
CAPACITY 20,000 HP
STORAGE NIL
HEAD 72 FT.
KANANASKIS PLANT
CAPACITY 24,000 H.P.
STORAGE NIL
HEAD 72 FT.
BARRIER PLANT
CAPACITY 15,000 H.P.
HEAD 155 to 120 FT.
STORAGE 20,000 AC. FT.
GHOST PLANT
CAPACITY 37,850 H.P.
HEAD 110 to 75 FT.
STORAGE 75,000 AC. FT.
Morley
RUSSELL SITE
78,000 H.P.
HEAD 141 to 101 FT.
STORAGE 78,000 AC. FT.
RADNOR SITE
33,000 H.P.
HEAD 60 FT.
STORAGE NIL
Cochrane
GLENBOW SITE
48,000 HP
HEAD 100 FT.
STORAGE NIL
BEARSPAW SITE
25,000 H.P.
HEAD 66 FT.
STORAGE NIL
CALGARY
CALGARY WATER POWER SITE
9000 H.P.
STORAGE NIL
CHESTERMERE LAKE
PROPOSED RESERVOIR
CHESTERMERE SITE
12,500 H.P.
STORAGE NIL
PROPOSED CANAL
Carseland
SHEPARD SITE
120,000 H.P.
HEAD 300 FT.
STORAGE 51,000 AC. FT.
High River
CALGARY POWER LTD.
BOW RIVER DRAINAGE BASIN
SHOWING
EXISTING AND PROPOSED
POWER DEVELOPMENTS
Scale
Date - April 17, 1952


BANFF HIGHWAY
Tp. 25
Tp. 24
RANGE 1
RANGE 2
RANGE 3
16th Ave. N.
BEARSPAW SIDING
Site of Ice Trap
Upper Bearspaw Damsite
Lower Bearspaw Damsite
BOW
Alberta Ice Co. Plant
BOWNESS PARK
BOWNESS BRIDGE
TWIN BRIDGES
RIVER
BOWNESS
RIVER DRIVE
SHOULDICE BRIDGE
MONTGOMERY
BRICKBURN
LOWERY GARDENS
Old City Pumping Plant
HILLHURST
Kensington Road
SUNNYSIDE
LOUISE BRIDGE
CENTRE ST. BR.
LANGEVIN BRIDGE
NORTH BR.
ST. GEORGES IS.
SOUTH BR.
C.N.R. BR.
12 AVE BR.
C. & E. BR.
W.I.D. DAM
CUSHING
17th Ave.
McLEOD TRAIL BR.
25th AVE BR.
MISSION BRIDGE
ELBOW
ELBOYA BRIDGE
RIVER
GLENMORE DAM
C
A
L
G
A
R



Lower end of excavation below Cushing Bridge
CUSHING BRIDGE
W.I.D. DAM
C.P.R. Bridge (Edmonton line)
South Bridge to St. Geo. Is.
North Bridge to St. Geo. Is.
MOUTH of ELBOW RIVER
Head of St. Geo. Is.
LANGEVIN BRIDGE
CENTRE ST. BRIDGE
3rd St. W.
7th St. W.
LOUISE BRIDGE
16th St. W.
19th St. W.
21st St. W. (OLD CITY PUMPHOUSE)
25th St. W. (North channel)
27th St. W.
32nd St. W.
WESTERN CITY LIMITS (37th ST. W.)
Staff Gauge
Staff gauge on tree
SHOULDICE BRIDGE
MAXIMUM BACKWATER STAGE ABOVE 3300 C.F.S. ICE FREE LEVEL
FEET
0
5
10
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
HORIZONTAL DISTANCE IN FEET ALONG RIVER



CALGARY POWER LTD.
PLOT OF
MAXIMUM-OBSERVED BACKWATER STAGES
ON
BOW RIVER
WINTERS 1947-51 INCLUSIVE
FROM
CUSHING BRIDGE TO BOWNESS BRIDGE
(Zero backwater equals 3300 c.f.s. ice free stage)
Revised and corrected April 23/52
C.O. 3767

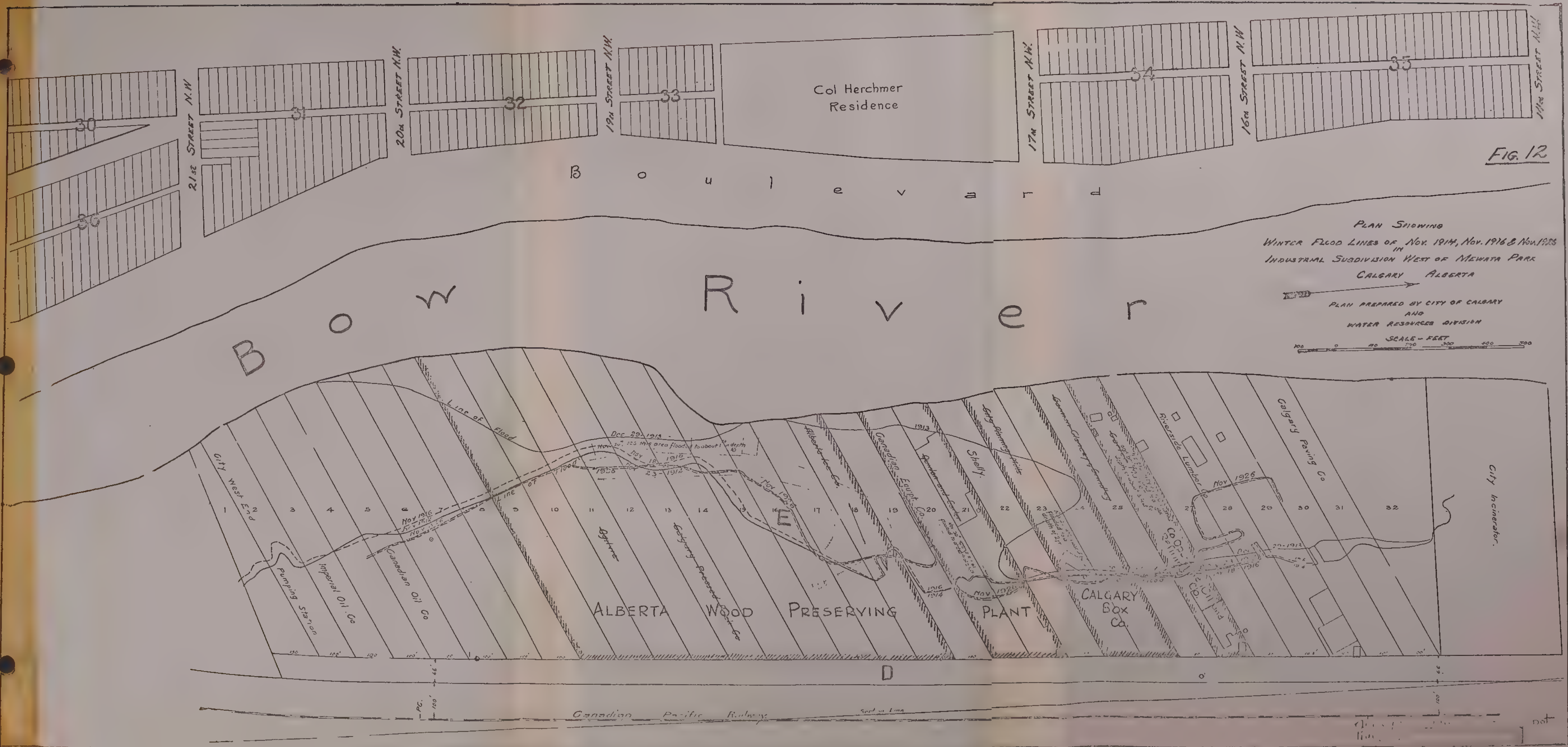
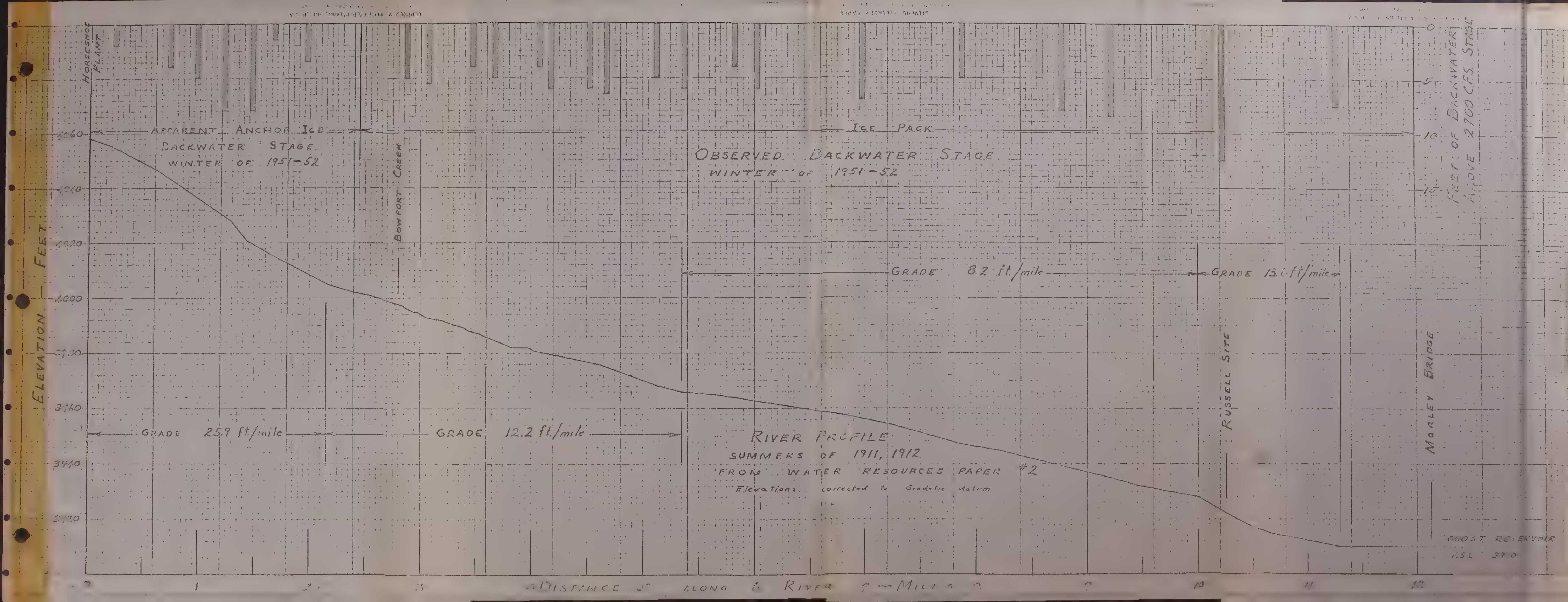


Fig. 12
Plan Showing
Winter Flood Lines of Nov. 1914, Nov. 1916 & Nov. 1926
in
Industrial Subdivision West of Mewata Park
Calgary Alberta
Plan prepared by City of Calgary
and
Water Resources Division
Scale – Feet
Col Herchmer Residence
21st Street N.W.
20th Street N.W.
19th Street N.W.
17th Street N.W.
16th Street N.W.
14th Street N.W.
Boulevard
Bow River
Line of Flood
Dec 29-1913
Nov 1916
Nov 1926
City West End
Pumping Station
Imperial Oil Co
Canadian Oil Co
Alberta Ice Co.
Canadian Equipt Co.
Shell
Riverside Lumber Co
Calgary Paving Co
City Incinerator
Alberta Wood Preserving Plant
Calgary Box Co.
Canadian Pacific Railway



Horseshoe Plant
Apparent Anchor Ice
Backwater Stage
Winter of 1951-52
Ice Pack
Observed Backwater Stage
Winter of 1951-52
Bowfort Creek
Grade 8.2 ft./mile
Grade 13.8 ft/mile
Russell Site
Morley Bridge
Grade 25.9 ft/mile
Grade 12.2 ft./mile
River Profile
Summers of 1911, 1912
From Water Resources Paper #2
Elevations corrected to Geodetic datum
Ghost Reservoir
F.S.L.
Elevation — Feet
Feet of Backwater Above 2700 C.F.S. Stage
Distance along River — Miles
4060
4040
4020
4000
3980
3960
3940
3920
0
5
10
15
0
1
2
3
10
11
12

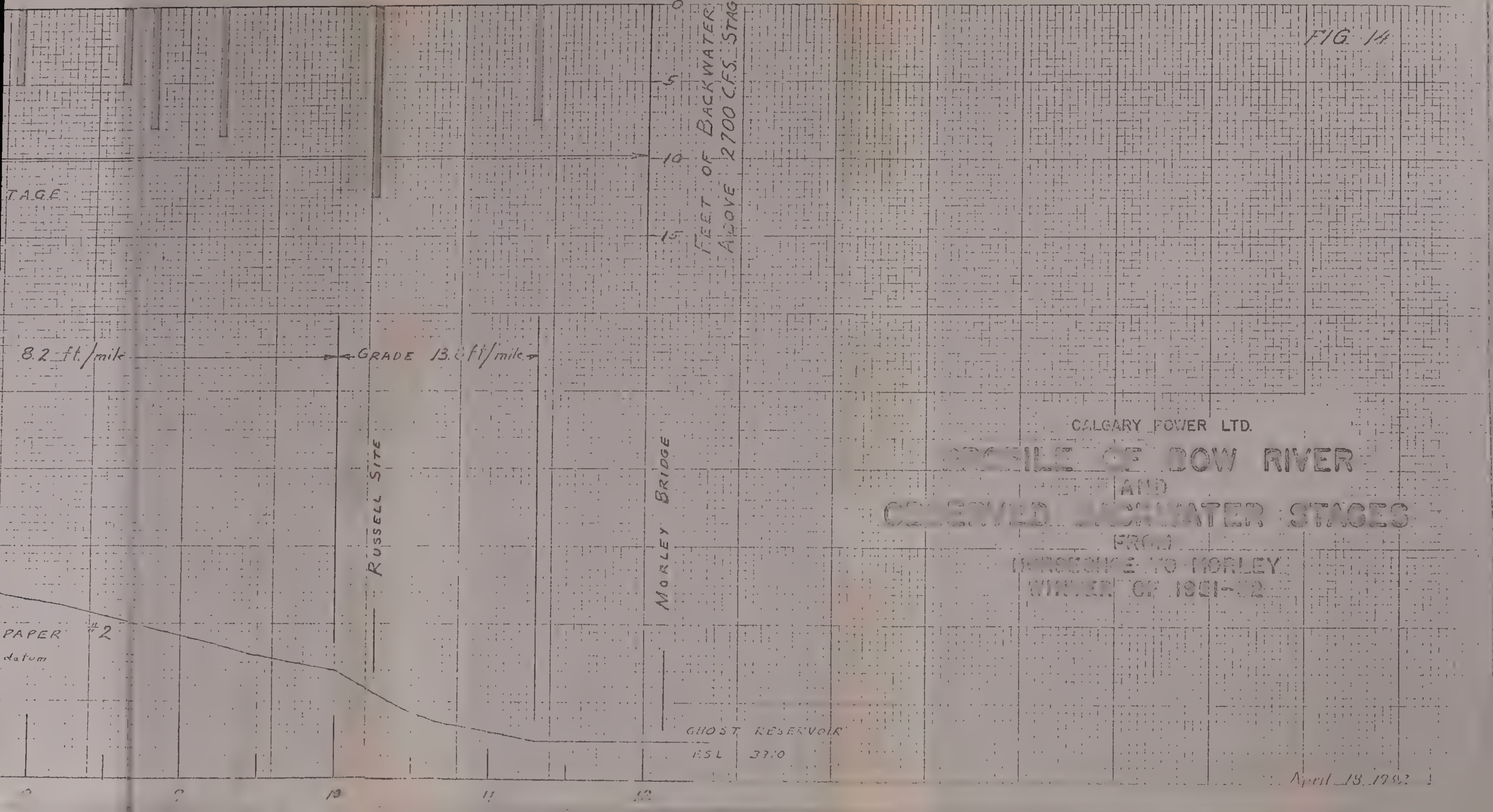

FEET OF BACKWATER ABOVE 2700 C.F.S. STAGE
0
5
10
15
TAGE
8.2 ft./mile
GRADE 13.8 ft/mile
RUSSELL SITE
MORLEY BRIDGE
PAPER #2
datum
GHOST RESERVOIR
F.S.L. 3310
10
11
12
CALGARY POWER LTD.
PROFILE OF BOW RIVER
AND
STAGES
FROM
TO MORLEY
April 18, 1952

FIG. 14

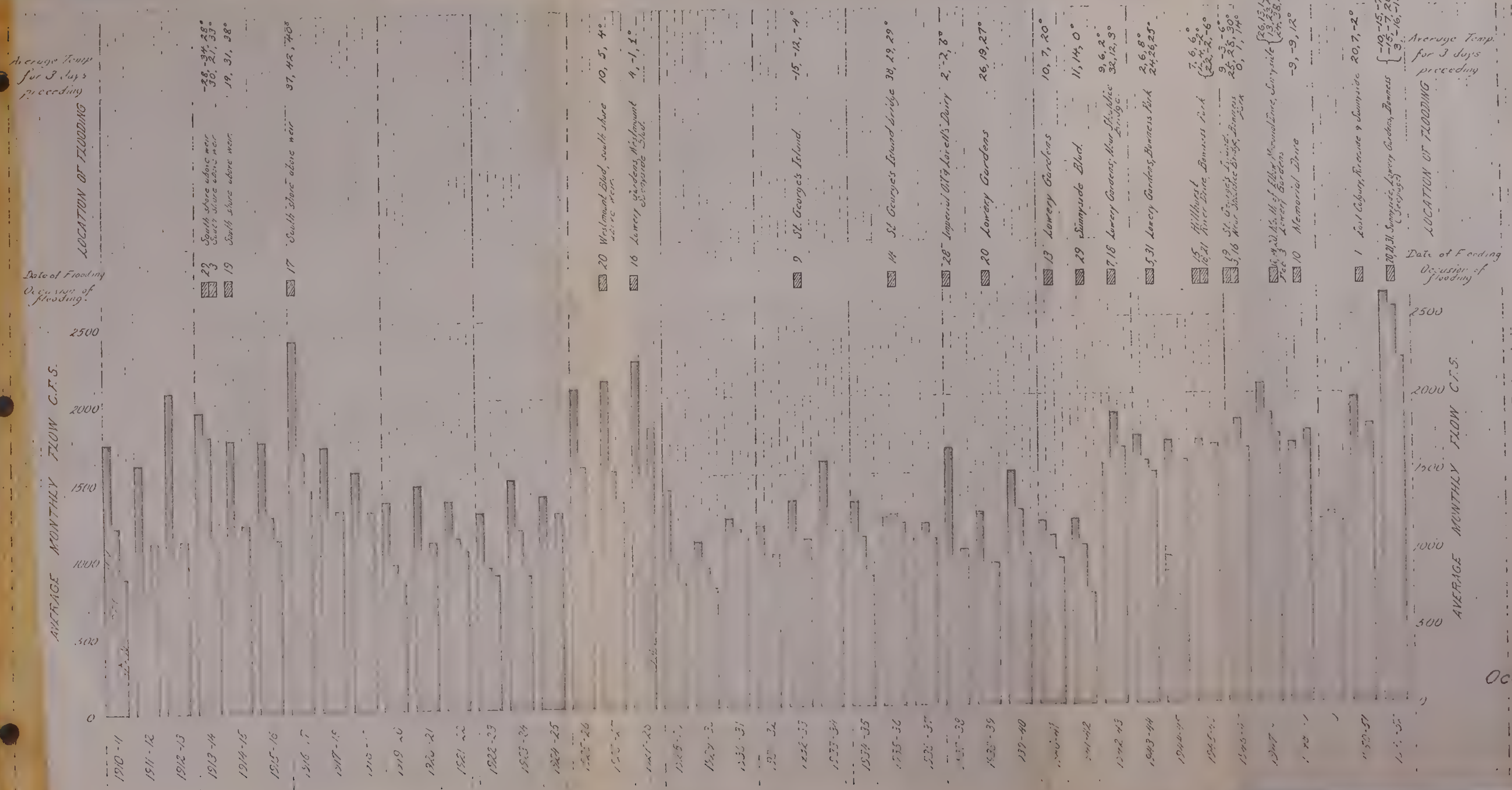


FIG. 15

CALGARY POWER LTD.

CHART OF

MEAN MONTHLY FLOWS

BOW RIVER AT CALGARY

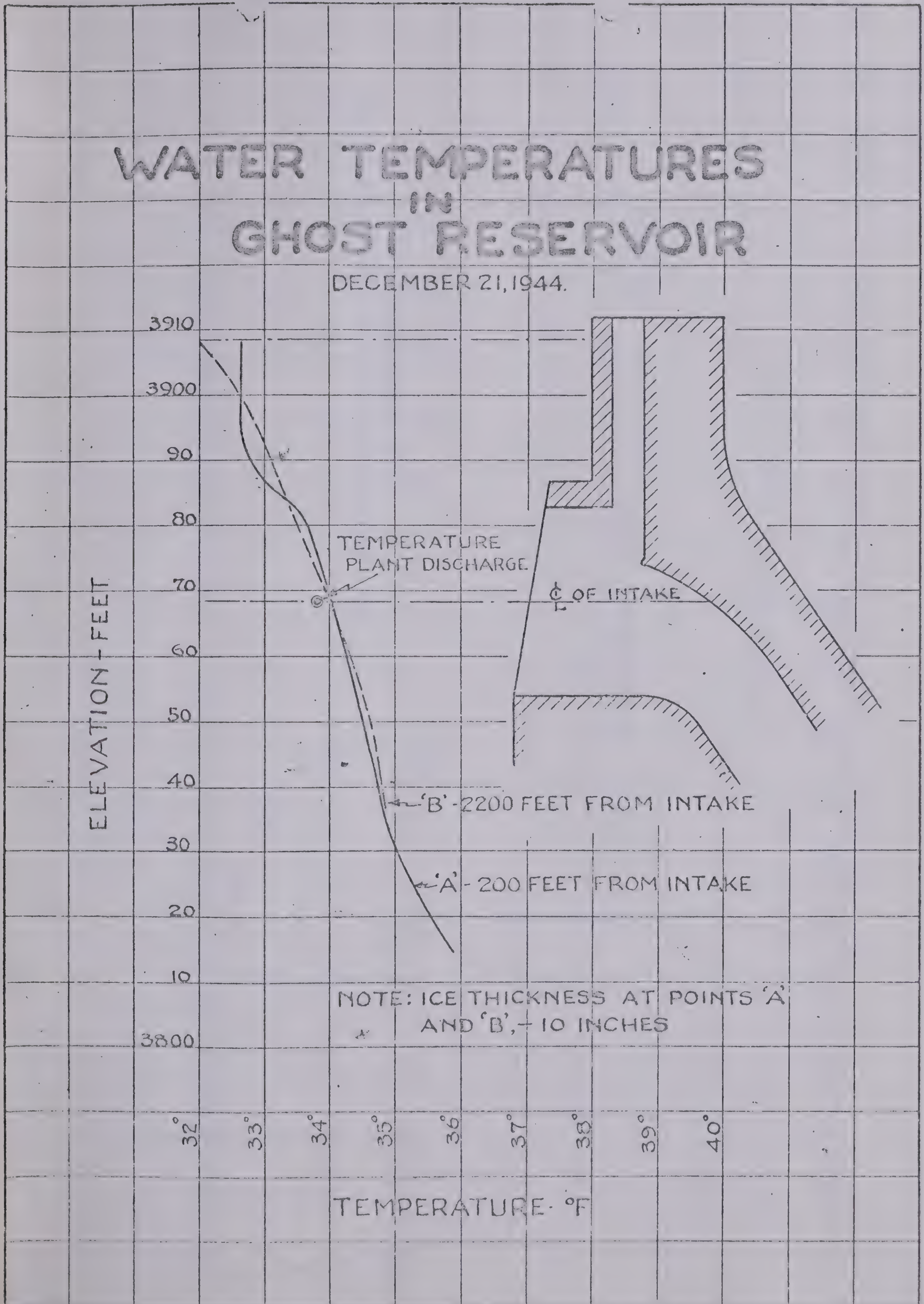
AND

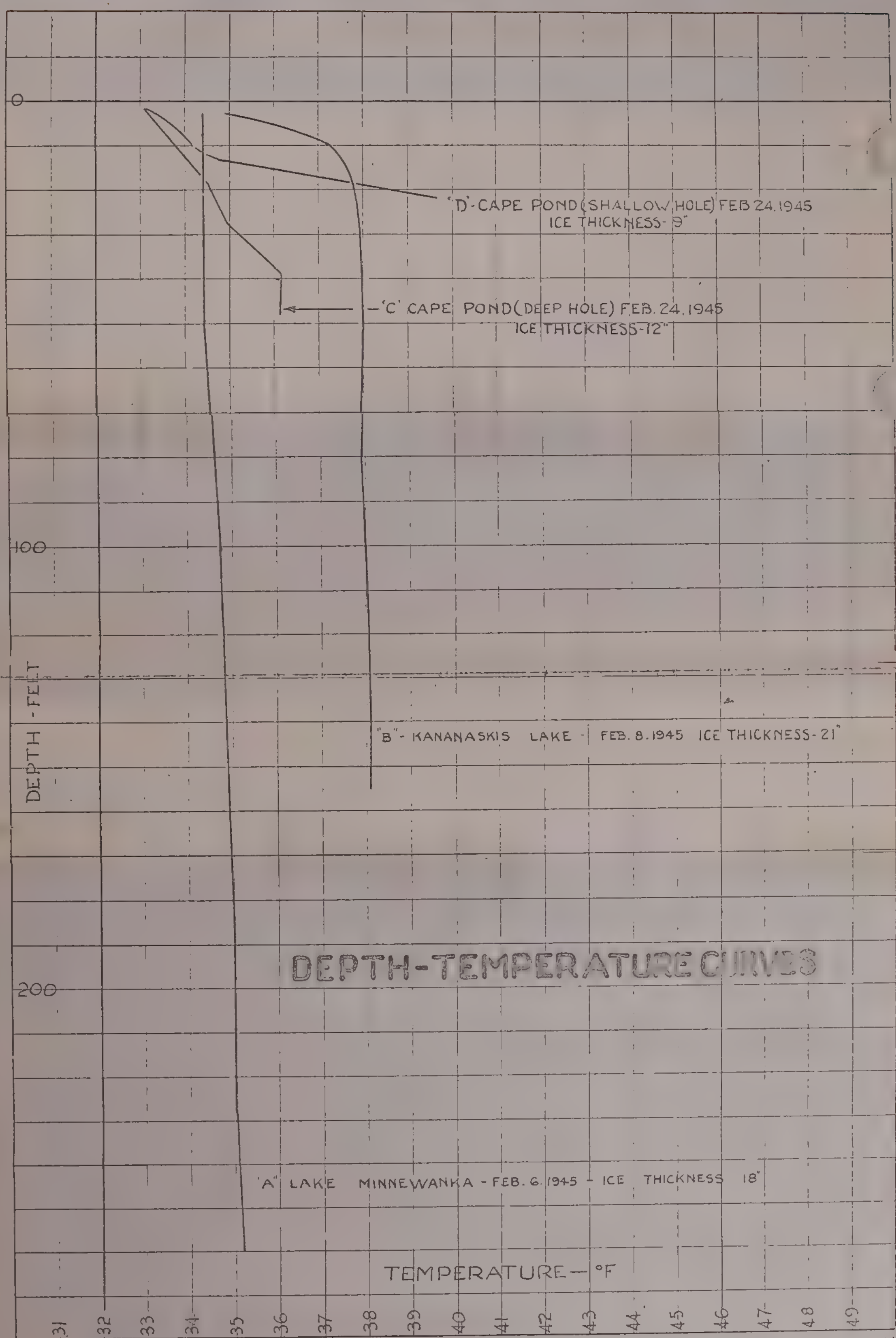
OCCASIONS OF RECORDED WINTER FLOODING

1910 – 1952

APRIL 23/52

Figure 16


WATER TEMPERATURES
IN
GHOST RESERVOIR
DECEMBER 21, 1944.
3910
3900
90
80
70
60
50
40
30
20
10
3800
ELEVATION - FEET
TEMPERATURE
PLANT DISCHARGE
℄ OF INTAKE
'B' - 2200 FEET FROM INTAKE
'A' - 200 FEET FROM INTAKE
NOTE: ICE THICKNESS AT POINTS 'A'
AND 'B', - 10 INCHES
32°
33°
34°
35°
36°
37°
38°
39°
40°
TEMPERATURE °F



DEPTH-TEMPERATURE CURVES
"D"-CAPE POND (SHALLOW HOLE) FEB 24.1945
ICE THICKNESS-9"
-'C' CAPE POND (DEEP HOLE) FEB. 24. 1945
ICE THICKNESS-12"
"B"- KANANASKIS LAKE - FEB. 8. 1945 ICE THICKNESS-21"
'A' LAKE MINNEWANKA - FEB. 6. 1945 - ICE THICKNESS 18"
DEPTH - FEET
0
100
200
TEMPERATURE — °F
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

Fig 17

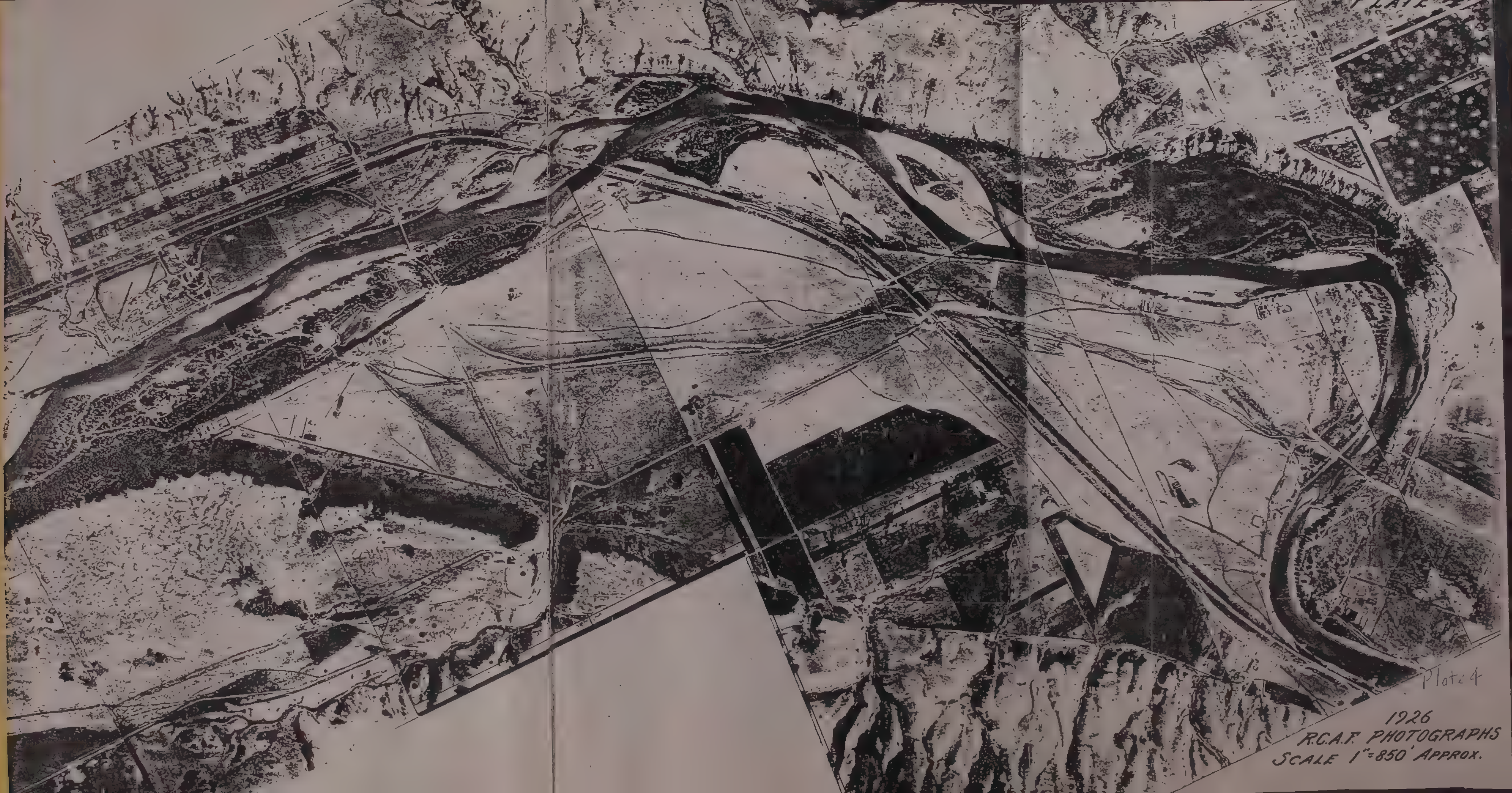


Plate 4

1926
R.C.A.F. PHOTOGRAPHS
SCALE 1" = 850' APPROX.

PLATE 5

1949
R.C.A.F. PHOTOGRAPHS
SCALE - 1" = 900' APPROX.